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ABSTRACT

This collection of lessons deals with nutrition in health and medicine and specifically the digestive system and its functions. The primary objective of this collection of lessons is to provide information on what constitutes good nutrition. Among the problems treated in these lessons are heart disease, peptic ulcer, hepatitis, vitamin deficiency diseases, parasitism, and dental problems. Each lesson contains: (1) a rationale; (2) objectives; (3) sequence; (4) suggestions; (5) teaching notes; (6) anticipated results; and (7) answers to questions presented in the student text. (Author/RE)

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SE 028 510

BIOMEDICAL SCIENCE

UNIT II

NUTRITION IN HEALTH AND MEDICINE

DIGESTION OF FOODS; ORGANIC CHEMISTRY OF
NUTRIENTS; ENERGY AND CELL RESPIRATION;
THE OPTIMAL DIET; FOODBORNE DISEASES; FOOD
TECHNOLOGY; DENTAL SCIENCE AND NUTRITION

INSTRUCTOR'S MANUAL
REVISED VERSION, 1975

THE BIOMEDICAL INTERDISCIPLINARY CURRICULUM PROJECT
SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

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INTRODUCTION

Unit II deals with nutrition in health and medicine. Just as the central theme of Unit I was the respiratory system and respiration, Unit II considers the digestive system and its functions. The two systems are functionally related. The digestive system breaks foods down into substances such as glucose, which the cells in turn break down to CO_2 and H_2O. The latter process is dependent upon oxygen, which is obtained in breathing, and one of the major end-products is CO_2, which is expelled in breathing.

The subject of nutrition has a great deal of medical significance. The primary objective of this unit is to provide information on what constitutes good nutrition, so that each student may select a diet of high nutritional quality (his or her optimal diet). An inappropriate diet can contribute to countless health problems, ranging from arteriosclerosis to obesity and caries. Among the numerous important medical problems treated in this unit are heart disease, peptic ulcer, hepatitis, appendicitis, diabetes, vitamin-deficiency diseases, food poisoning, pinworms, dental malocclusion and periodontitis.

A. CONTENT OF THE UNIT:

This unit on nutrition considers the following topics in order: digestion and the digestive system, the biology and chemistry of nutrients, energy and cell respiration, the optimal diet, food microbiology, food technology and dental health. The following paragraphs briefly describe the five major parts of the unit.

PART I: DIGESTION (Lessons 1 to 9)

The first two lessons introduce the unit by describing the relation between nutrition and one of our most serious and widespread health problems, heart disease. The next six lessons introduce the anatomy and physiology of the digestive system. Diseases that affect the organs of the digestive tract are considered where relevant. Laboratory activities in this sequence include dissection, a study of enzymatic catalysis, analysis of blood in simulated stool specimens and analysis of gallstones.

PART II: CHEMICAL AND BIOLOGICAL PROPERTIES OF NUTRIENTS (Lessons 10 to 21)

A knowledge of nutrition requires an understanding of the composition of foods. Lessons 10 through 21 treat selected topics in nutritional chemistry. These lessons introduce organic chemistry with specific reference to carbohydrates and other nutrients. Health problems related to nutrition--e.g., glycemia, rickets and goiter--are introduced at appropriate points in the sequence. The major laboratory activity is a quantitative analysis of the fat, protein and water content of foods. This analysis will occupy several periods. In other activities students will work with molecular models, measure the heat capacity of water, and analyze for vitamin C in fruit juice and riboflavin in vitamin pills.

PART III: ENERGY, METABOLISM AND THE DIET (Lessons 22 to 33)

Providing energy is one of the main functions of nutrition. This sequence begins with three lessons on energy, particularly chemical energy. These lessons are followed by a brief analysis of cell respiration, the process by which the products of digestion release energy that the cells use for production of ATP. Lessons 27 and 28 introduce chemical equilibria and show how ATP alters chemical equilibria and thus increases the output of endothermic reactions. The final lessons in this sequence return to a major theme of the unit, the optimal diet.

In LA-22 and LA-23 chemical reactions and heats of reaction are considered. Following a simulation game on cell respiration, the activities return to chemical reactions and focus on Le Chatelier's principle. In addition, there is a series of activities in which students analyze their energy requirements and their diets. These activities lead to an evaluation of the quality of their diets and to the designing of optimal diets for themselves.

PART IV: FOODBORNE DISEASE (Lessons 34 to 39)

This sequence considers health problems associated with food contaminants and additives. The first three lessons consist of a study of food microbiology and water pollution, including pertinent laboratory activities. Other lessons deal with the effects of processing and additives on food quality. In the laboratory, the students analyze for nitrite in meats. The last lesson in this series demonstrates how to derive useful information from food labels. An activity on reading food labels is included.

PART V: DIET AND DENTAL DISEASE (Lessons 40 to 43)

The final four lessons provide a brief treatment of the teeth and dental disease. The rationale for including these lessons in a unit on nutrition is that (1) the mouth and teeth play an important role in digestion and (2) nutrition, in turn, plays a significant role in dental health. The activities in this section involve the teeth, dentition and plaque.

B. UNIT OBJECTIVES:

The student will

- identify the organs of the digestive system and their functions.
- list and describe at least three diseases associated with the digestive system.
- list and describe at least two clinical procedures used in diagnosing disorders of the digestive tract.
- describe the changes that occur in nutrients during digestion.
- recognize several functional groups (i.e., $-OH$, $-COOH$, $-NH_2$) and indicate in which nutrients they are found.
- list and describe the functions of the three classes of nutrients that can provide energy (i.e., fats, proteins and carbohydrates).
- explain how to analyze for fats and proteins in foods.
- list at least three minerals and at least three vitamins and describe their functions
- explain the relation between the energy stored in nutrients and the synthesis of ATP.
- explain the relation between pulmonary respiration and cell respiration.
- explain how changes in the concentrations of reactants and products affect a reversible reaction.
- explain how to use food tables to evaluate a diet.
- describe the characteristics of diabetes mellitus and obesity and how diet may be employed in the treatment of these conditions.
- list at least three microbial diseases and describe how these diseases may be prevented.
- list advantages and disadvantages of food processing and food additives.
- list at least three dental health problems along with information on prevention and treatment of each.
- explain how diet is related to dental health.

This volume contains teacher materials for a total of 43 lessons on nutrition. A Student Text and Laboratory Manual are available in separate volumes.

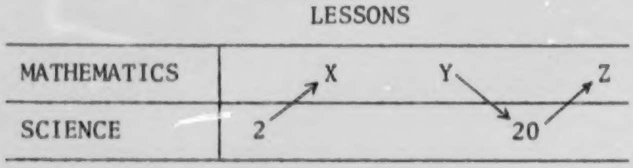
C. INTERDISCIPLINARY TIES:

1. Biomedical Mathematics: As in Unit I, close contact with other Biomedical teachers is essential. Of particular importance in this unit is the relationship and coordination between Mathematics and Science. The following four ties between the two disciplines deserve special consideration. Additional ties are suggested in individual lessons.

a. Graphing is emphasized in Science Lessons 1 and 2. This ties with Supplementary Mathematics Lesson X, which is found at the end of Mathematics Unit II. Mathematics Lesson X should be taught immediately after Science Lesson 2. You should discuss this tie with the Mathematics instructor.

b. The vitamin C laboratory activity (Science LA-20) is closely related to Mathematics Lessons Y and Z. Error analysis in Mathematics is applied to this Science activity. You and the Mathematics instructor should coordinate your schedules so that Mathematics Lesson Y is taught just before LA-20 and Mathematics Lesson Z is taught immediately after LA-20.

These ties between Science and Mathematics can be more easily understood from the following diagram.



c. In order to take advantage of diet-analysis techniques developed in Mathematics, Science instructors may benefit by reading the Mathematics lesson "Introduction to Vectors" before beginning Science Unit II. Such vector treatment may also be used in Science Lesson 31, on optimal diets.

d. Before teaching the section on "optimal diet," you may want to confer with the Mathematics instructor to see the kinds of problems treated in Mathematics lessons on linear programming (Mathematics Sections 19-21).

2. Biomedical Social Science: The ties between Unit II of Social Science and Science are of a more general nature. They can be best understood from the following outline of Unit II Biomedical Social Science.

Lessons 1-16: The focus of these lessons is on culture and ways of learning about culture, and the lessons give little attention to health or nutrition. Materials provided for students illustrate concepts and methods with reference to a variety of cultures. Some of the information about other cultures is related to food production and distribution.

Lessons 17-37: During this sequence the class is divided into groups and each group uses a different Student Text plus outside resources. The groups base their investigation on ten question sets about various aspects of culture. These question sets are in the Biomedical Social Science Student Text, Unit II, Part One, pp. 141-145.

Half the question sets (sets six through ten) are about health. Their topics are: ways of thinking and acting about health, disease and death; the health status of the people being studied; nutrition and its effects on health; the effects of ideas and social structure on health; and the effects of the environment on health. Each of these question sets requires, to one degree or another, that students review materials from Biomedical Science Unit I or Unit II.

The other five question sets (one through five) are not directly related to nutrition and health, but some of them require collection of data that might help to explain the nutritional and health status of the people being studied. The topics of these question sets are: the influences of culture and environment on each other; ways of making a living and division of labor; ritual and religion; leadership, power and rules; and family life and child rearing.

Lessons 38-40: In these lessons groups of students attempt to design Western-style health centers which are adaptable to all the cultures studied in the preceding lessons, and which deal with the following four types of health problems: environmental quality, respiratory diseases, gastrointestinal diseases and nutrition. Students will need to review materials from Biomedical Science Unit I in dealing with the first two types of problems, and materials from Biomedical Science Unit II in dealing with the other two. Evaluation will be based equally on the appropriateness of the health center plan to the various cultures (a social-science problem) and on the appropriateness of the measures suggested for solving the specific health problems (a science problem). The Instructor's Manual for Biomedical Social Science suggests that both the Science and the Social Science instructors participate in the evaluation of the health center plans and of the students' analysis of other groups' plans.

D. CAREER INFORMATION:

Biomedical Science Unit II has many career implications, and field trips to visit specialists could be a very worthwhile supplement. Conversely, you may wish to invite specialists to visit your classroom. Either idea will take some advance planning. To get the best use out of outside speakers, you may find the following table useful. It lists particular careers and the relevant lessons where each specialist might be useful. Specialists who work in a hospital can often be contacted through a hospital administrator.

Specialist	Relevant Lesson(s)
epidemiologist	1, 2
statistician	1, 2
anatomist or physiologist	3, 5, 7, 8, 14
biochemist	4, 12, 15, 17, 25, 26
physician (internist)	6, 9, 14, 32, 33, 35
medical technologist	6-9, 32, 34
X-ray technologist	6, 9
surgeon	6, 8
virologist	9
psychologist	9
chemist	10, 22, 23, 27, 28
organic chemist	11, 12, 15
food analyst	12, 20, 38
nutritionist	16, 18, 20, 21, 30-32, 39
physicist	22, 23
electron microscopist	26
dietitian	30-33
anthropologist	30, 42
medical microbiologist	34-36
veterinarian	35
food technologist	37, 38
food and drug inspector	38
dentist	40-43
orthodontist	41
dental hygienist	42

Information on the functions of different types of dietitians is appended to this Introduction. Note that the information is aimed at students (rather than teachers). You may wish to post this information at the appropriate time. or to make copies for your class.

Field trips would be a convenient supplement to most of the lessons listed above. Besides visits to the specialists mentioned, you may wish to consider visits to the following sites:

- water-treatment plant (Lesson 36)
- food-processing plant (Lesson 37)
- dental college (Lessons 40-43)

E. LABORATORY ACTIVITIES REQUIRING ADVANCE PREPARATION:

1. Live earthworms are needed in LA-3. They should be ordered to arrive about one day in advance of the activity.

2. Gallstones are required for LA-7 and LA-8. They should be requested in advance as directed in the Teaching Notes for LA-7.

3. LA-30 requires a number of sets of special calipers ("fat-grabbers"). Directions for making the calipers may be found in the Teaching Notes for LA-30. It will take some time to make these, so you may wish to get started well in advance of LA-30, or assign students to make their own.

4. The Teaching Notes for LA-40 suggest the possibility of obtaining materials from a dentist. Doing so will require some advance planning and communication.

One or two additional comments about the laboratory activities should be made at this point.

A significant number of the activities in Unit II involve colorimetry, a key tool in clinical medicine. It would be good to be sure early in the unit that the BIP's are functioning well when programmed for colorimetry. In addition, if you have not already done so, it would be a good idea to number the colorimetry test wells so that each student can use the same BIP and test well in activities that last longer than one day.

The activities are designed to permit increasing student input into both the planning and analysis of investigations. For example, LA-4 allows students to design an investigation of the effect of pH on amylase activity. Later activities will provide greater challenges.

F. BIBLIOGRAPHY:

You can obtain numerous reference books on the subjects covered in Unit II. A few references that were useful in the development of this unit are listed in this Bibliography. This is not a comprehensive list, and you may find other references of more value to you.

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R.M. De Coursey, The Human Organism, 4th ed., McGraw-Hill Book Co., N.Y., 1974.

B.R. Landau, Essential Human Anatomy and Physiology, Scott, Foresman and Co., Glenview, Ill., 1976.

S.R. Williams, Nutrition and Diet Therapy, C.V. Mosby Co., St. Louis, 1970.

L.J. Bogert, G.M. Briggs and D.H. Calloway, Nutrition and Physical Fitness, 9th ed., W.B. Saunders Co., Philadelphia, 1973.

H.S. Mitchell, et.al., Cooper's Nutrition In Health and Disease, 15th ed., J.B. Lippincott Co., Philadelphia, 1968.

ADDENDUM:

Nutritionists and Dietitians

Two professions involved in the field of nutrition are those of the nutritionist and the dietitian.

A nutritionist is an educator who is concerned with teaching people how to satisfy their normal nutritional needs. A nutritionist typically works for a government-financed health organization. For example, a nutritionist may work with a community health service. Work may include nutrition education in schools and day-care centers, advising outpatients and being available for consultation in family meal planning.

A dietitian has a college degree and obtains training as an intern in a clinical situation, such as a hospital. The field in which a dietitian works is called dietetics. Dietetics is the application of nutritional knowledge to specific situations. The subject of dietetics includes a wide range of areas of interest; a dietitian may specialize in any of a number of areas. A dietition may be concerned with the dietary treatment of illness or with the proper diet for normal growth and health. He may also apply dietary knowledge to planning menus and administering the preparation of food for large groups of people.

A dietitian may work in a hospital, in a community or in an industry: We will consider briefly the function of dietitians in each of these areas.

Hospital Dietitians

1. Clinical or therapeutic. A dietitian obtains a patient's diet history, studies possible diet therapies and takes part in decisions concerning the patient's diet. The dietitian then plans a specific diet and discusses it with the patient.

2. Administrative. The management of food services and personnel is in the charge of a dietitian. He is in charge of food purchasing, meal planning and preparation both for patients and employees. Smaller hospitals may have only one or two dietitians who must both administer the hospital's food service and consult with individual patients.

3. Research. Some hospitals conduct dietary research. The purpose is to study the effect of diet on specific ailments. Dietitians help plan the diets and monitor the quantities of foods actually eaten by patients.

Community Dietitians

1. School food services. A dietitian manages school food services programs. One dietitian may manage the lunch programs of several elementary and secondary schools. Dietitians working in colleges and universities administer the food services in dormitories, faculty dining clubs and snack bars.

2. Consultants. Many dietitians work as consultants to small institutions such as retirement homes, convalescent homes and day-care centers.

Industrial Dietitians

1. The food industry. Dietitians are involved in research in the food industry. Experimentation is required to obtain information on new food products. Dietitians are also involved in developing new products and marketing them. The Dairy Council, for example, employs dietitians who conduct workshops in nutrition education for teachers and other dietitians.

2. Food management companies. Special companies provide food service to restaurant chains, airlines and large hospitals. The company provides equipment, supplies and personnel. The personnel include an administrative dietitian to supervise the selection, purchase and preparation of food.

3. Grocery stores. Some grocery stores employ dietitians. The dietitians demonstrate products and provide information to consumers.

Dietetics and Therapy

Imagine that you are a dietitian in a hospital. You are a therapeutic dietitian; you work with individual patients and are part of the team that provides the optimal diet for a patient. Your goal is to establish a diet that is as nutritionally adequate as possible given the restrictions placed on it by the patient's condition. At the same time the diet must be acceptable to the particular patient and must interfere with the patient's life as little as possible.

Imagine that a patient has been admitted to the hospital. He has been examined and tested by his doctors, and a diagnosis has been made. The diagnosis is that the patient is suffering from a disease in which diet is an important part of the treatment. The patient's recovery requires that his diet be modified.

The patient's doctor consults with you, as a therapeutic dietitian. He explains the disease and its relation to diet. The doctor prescribes a diet; it is then your job to see that his diet order is carried out.

You next talk with the patient. You find out the patient's eating habits: his likes and dislikes, who prepares his meals, how much and how often he eats. You also ascertain his financial status to see whether the cost of the new diet must be taken into consideration. You must also determine his present diet, because the nutritional value of this diet provides important information.

During this interview you must also try to judge how good the patient will be at sticking to his diet. Your judgment is based in part on the importance the patient attaches to his present diet. If the patient is careful in his present dietary habits, you may expect that he will be careful in following the modified diet. You and the patient then agree on a diet that is both satisfactory to the patient and suitable to his medical requirements (and to the hospital's budget).

Your next task as therapeutic dietitian is to inform the dietary department of the hospital about the diet you and the patient have agreed upon. Many people are involved in seeing that the dietary orders are carried out. Clerks compile menus and keep files on each patient. The preparation of the food in the kitchen may need to be supervised. You may check the tray before it is sent to the patient to be sure no mistakes were made.

A therapeutic dietitian vists a patient frequently. Visits may be necessary to explain any diet changes the doctor has ordered, or simply to see whether the patient is eating his food. If the patient must continue the modified diet once he has returned home, the dietitian will give him instructions, explaining the specific foods to be eaten and procedures to be used in following the diet.

LESSON 1: (A) INTRODUCTION TO NUTRITION

(B) STATISTICS AND HEART DISEASE

RATIONALE:

ST-1 provides an introduction to the entire unit. The first activity introduces data that suggest a relation between nutrition and heart disease. It serves to reinforce the earlier treatment of graphing in Biomedical Mathematics as well as the previous treatment of population data in Biomedical Social Science. Finally, this exercise leads into the discussion of nutrition and heart disease in ST-2.

OBJECTIVES:

The student will:

- construct bar graphs from tabular data.
- write a concise statement summarizing the information in a table of data or in a bar graph.

SEQUENCE: ST-1; Activity 1

SUGGESTIONS:

1. You may wish to expand on the brief introduction to the unit in ST-1. A more detailed discussion of the organization of the unit is provided in the Introduction to the Instructor's Manual.

2. A discussion of the careers related to Unit II would be appropriate. Such a list of careers appears in the Introduction. Students have also investigated a variety of health careers in Social Science Unit I, Lessons 12 to 15. You might inquire about student interests in careers and discuss the possibility of field trips. The students may have contacts who can help set up field trips, or visit the class and speak about some aspect of nutrition.

3. Consider the possibility of having bulletin board space available for students to post newspaper and magazine clippings related to nutrition. There is much coverage of this topic and students could be assigned to collect clippings. This project would emphasize the timeliness and newsworthiness of the subject matter of this unit and may also provide you with information that can be used in later periods.

4. It would be good to be in contact with both your Biomedical Mathematics and Biomedical Social Science colleagues in regard to Activity 1. Interdisciplinary ties with Science Unit II were discussed in the Introduction.

INFORMATION ON ACTIVITY 1:

TEACHING NOTES:

1. One purpose of this activity is to provide students with a background for ST-2, which includes information on the Framingham and other epidemiological studies. A second purpose is to emphasize the importance of graphs and tables in medical research. In addition, this activity and ST-2 are related to Biomedical Mathematics Unit II, Section X, which concerns correlations. You may also wish to remind students of the connection with Biomedical Social Science Unit I, Lessons 19 to 21.

2. Anticipated time: one to two periods.

3. It should be emphasized that a statistical correlation between two variables does not prove that one causes the other. This point will be brought out more strongly in Biomedical Mathematics Section X. It is important to discuss this activity with your colleague in mathematics.

4. This activity may be shortened by omitting one or more parts, if desired. It may be extended by adding more questions or assigning additional graphing problems.

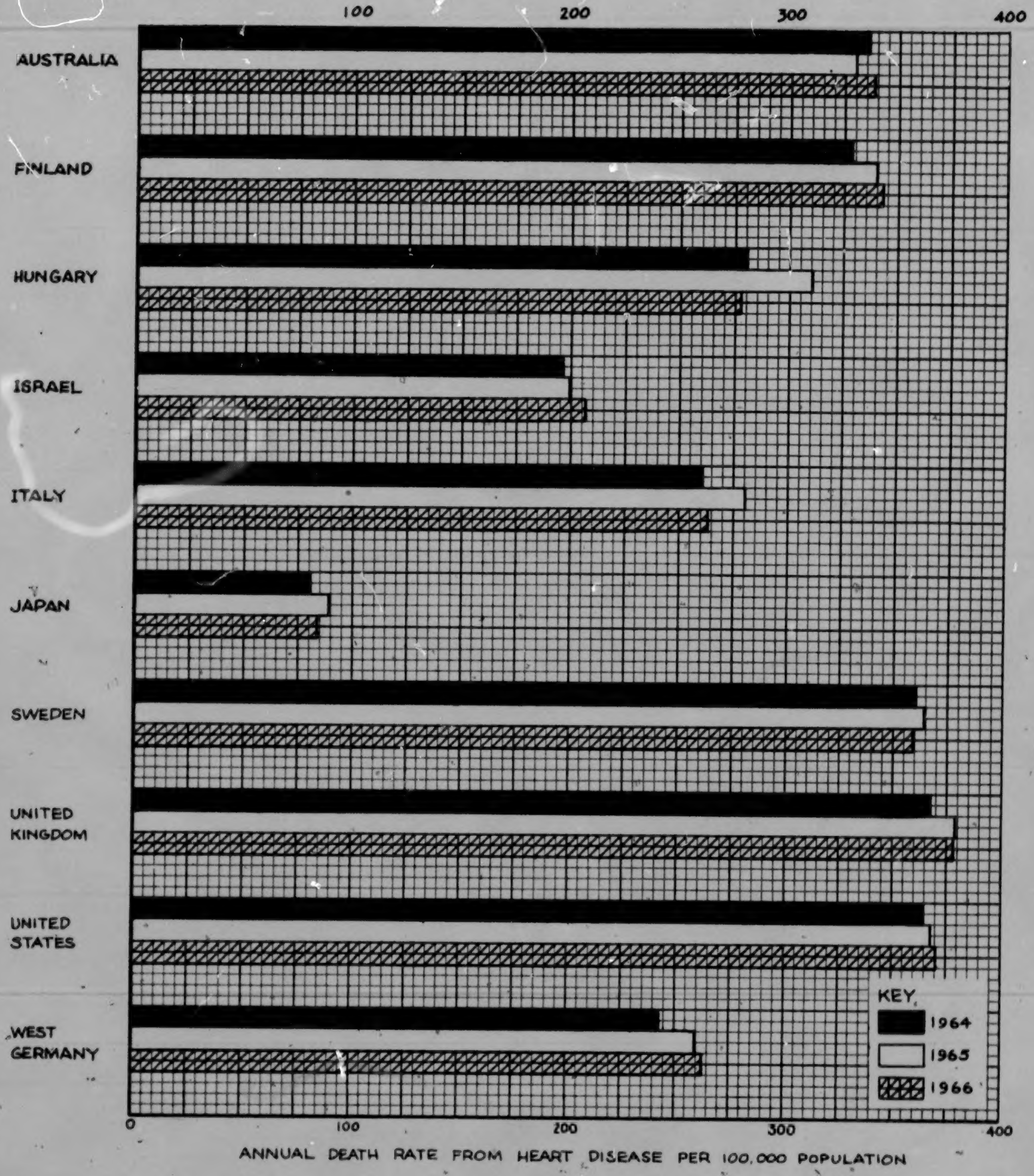
5. It is necessary to provide one sheet of graph paper per student for use in Part I.

6. Part IV is deliberately open-ended. It will be useful to have a class discussion so that students can see how different ideas can be obtained from the same graph.

7. Most of the data used in this activity were adapted from J. Stamler's review, "Epidemiology of Coronary Heart Disease." It was published in Medical Clinics of North America, Vol. 57, January 1973. The base year for many of the statistics discussed in the activity was 1967. The data include both atheroslerotic and degenerative heart disease. Many details concerning the data have been omitted. For example, some death rates are adjusted to account for the fact that some populations are older than others and the older people have a higher risk of heart disease.

ANTICIPATED RESULTS:

In Part I, the students were asked to convert the data in Table 1 to a bar graph. The solution follows.


100
200
300
400
AUSTRALIA
FINLAND
HUNGARY
ISRAEL
ITALY
JAPAN
SWEDEN
UNITED KINGDOM
UNITED STATES
WEST GERMANY
KEY
1964
1965
1966
0
100
200
300
400
ANNUAL DEATH RATE FROM HEART DISEASE PER 100,000 POPULATION

3

ANSWERS TO QUESTIONS:

PART I:

1. 88.6

2. .0886

3. Sweden, United Kingdom and United States; yes

4. Israel, Japan and West Germany; yes

5. 8

6. 2

7. West Germany

8. A table can provide more data in a limited space and generally shows quantities more accurately than a graph does. A graph can summarize data in a way that makes the results of a study more obvious. A graph can suggest trends and relationships.

PART II:

1. Finland

2. Japan

3. Italy

4. Finland, United Kingdom and United States

5. approximately 40%

6. approximately 46%

7. Australia, Sweden and perhaps United States

8. Japan

9. Yes

PART III:

1. Norway--large increase in death rate from heart disease in males and moderate increase in females.

United States--small increase in death rate for males, drop in death rate for females.

Japan--decrease in death rate for both sexes.

2. Ireland, Japan

3. Norway, Austria, South Africa, Australia, New Zealand

4. Netherlands, Denmark, Sweden, Scotland, Belgium, Italy, England and Wales, Canada, U.S., Switzerland; males increasing and females decreasing.

5. Overall, there was an increase in death rate from heart disease for males. The data on females are variable and there is no obvious trend.

PART IV:

1. There are many possible answers. The main point is that in those countries in which people consumed a greater proportion of saturated fatty acids, heart disease was more common. The data suggest a relationship between dietary intake of saturated fatty acids and the risk of heart disease.

2. Yes

3. No. They show a correlation, but do not prove that saturated fatty acids in the diet cause heart disease. This point will be emphasized in Biomedical Mathematics both in Section X and in the sections on chi-square.

LESSON 2: (A) HEART DISEASE AND NUTRITION

(B) EXAMPLES OF TEENAGE 24-HOUR DIETS

RATIONALE:

This is the second lesson in a sequence on food, health and the digestive process. An understanding of the relationship between nutrition and health will be of great long-range value to the students. This lesson relates nutrition to coronary heart disease by means of data from the Framingham study. In a sense, it is an extension of Activity 1.

The activity for this lesson is a study of the diets of two hypothetical teenagers. It focuses attention on the diet and nutrients--one of the main topics of the entire unit. This activity ties in closely with the kinds of calculations the students perform in Biomedical Mathematics, Unit II. In later science lessons, after a more thorough study of nutrition, the students will evaluate their own diets and consider how they may be improved.

OBJECTIVES:

The student will:

- define and explain the importance of coronary heart disease.
- describe how the Framingham Study was done and the conclusions regarding cholesterol.
- describe how the typical diet of North Kyrelians increases their risk of heart attack.
- describe the relationship between blood cholesterol level and heart disease.
- describe the trend in death rate from heart disease in the U.S.A. during this century.
- use a food table to determine the quantities of protein, fat and carbohydrate in a diet.

SEQUENCE: ST-2; Activity 2

SUGGESTIONS:

1. You could use Activity 1 as a transition to Lesson 2. You might also discuss some of the other aspects of the Framingham study described in the Background Information.

2. The case history in Section 2-1 could be used to start a discussion of the relation between nutrition and heart disease. Perhaps the students have close relatives who have had heart attacks. Students might compare the diets and other characteristics of such relatives with those of Fred Stone.

3. It is desirable for Biomedical Mathematics Lesson X on correlations to be taught soon after this lesson.

BACKGROUND INFORMATION ON THE FRAMINGHAM STUDY:

The Framingham Study is the largest, most prolonged and most carefully conceived epidemiological study of cardiovascular disease ever undertaken in the U.S. It was begun in 1949 in Framingham, Massachusetts, a retail and light industrial center and residential area 21 miles west of Boston. At the beginning of the study tho subjects included about 5200 men and women aged 30 to 62 and free of clinical evidence of heart or vascular disease. The results thus far indicate that four characteristics in males are associated, at a statistically significant level, with an excessive risk of developing heart and vascular diseases.

These four relationships are shown in Figures 1 through 3. These figures might be converted to transparencies for overhead projection. The following definitions apply to information on the graphs.

Angina pectoris--a form of coronary heart disease characterized by spasmodic attacks of intense pain originating in the heart muscle because of inadequate coronary blood flow. ("Angina pectoris" is Latin for "pain in the chest.")

Relative weight--the ratio of the subject's weight to the median weight for all subjects of the same height and sex, times 100. A relative weight of 120 indicates that the subject weighs 20% more than the median for his height and sex.

Relative incidence--100 times the ratio of the risk for a certain category of men to the risk for all men in the study. For example, Figure 1 shows that men with a relative weight of 120 or more had a risk of sudden death from coronary attack that was 365% or 3.65 times that of all Framingham men. One can also calculate that the risk of sudden death for men with a relative weight of 120 or more was about 5 times (365 divided by 75) the risk for men with a relative weight of less than 120.

Blood cholesterol concentration--actually, milligrams of cholesterol per 100 milliliters of serum. Serum is the clear fluid that remains after blood has clotted. Note that the term "serum" was not introduced in the text.

All of the Framingham data displayed apply only to men. Associations between coronary heart disease and the characteristics shown are less strong for women, but similar trends exist for them. Although four men die for every woman who dies of coronary heart disease, there are nevertheless some 80,000 female coronary deaths in the U.S. each year.

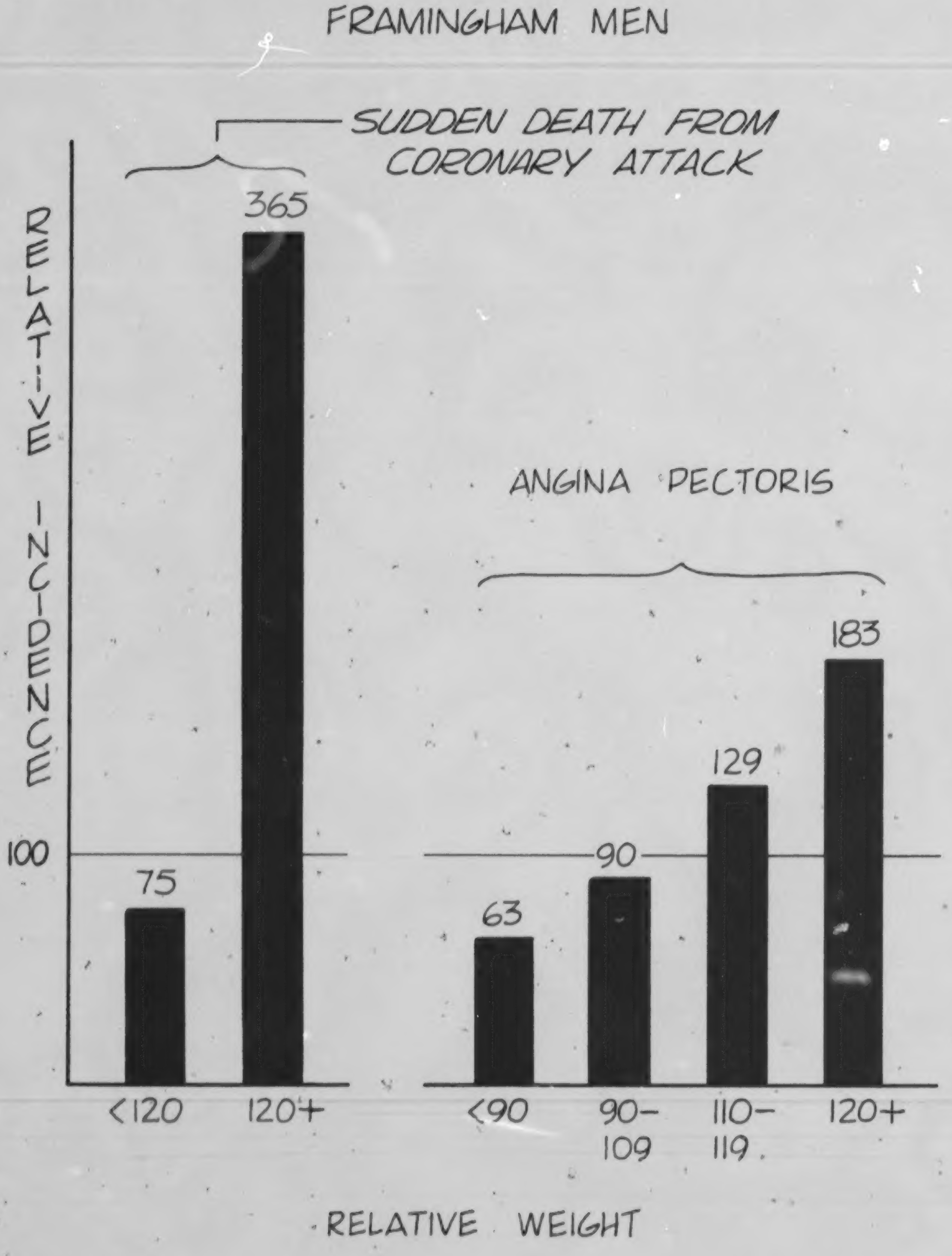

FRAMINGHAM MEN
SUDDEN DEATH FROM CORONARY ATTACK
ANGINA PECTORIS
RELATIVE INCIDENCE
100
75
365
63
90
129
183
<120
120+
<90
90-109
110-119
120+
RELATIVE WEIGHT

FIGURE 1

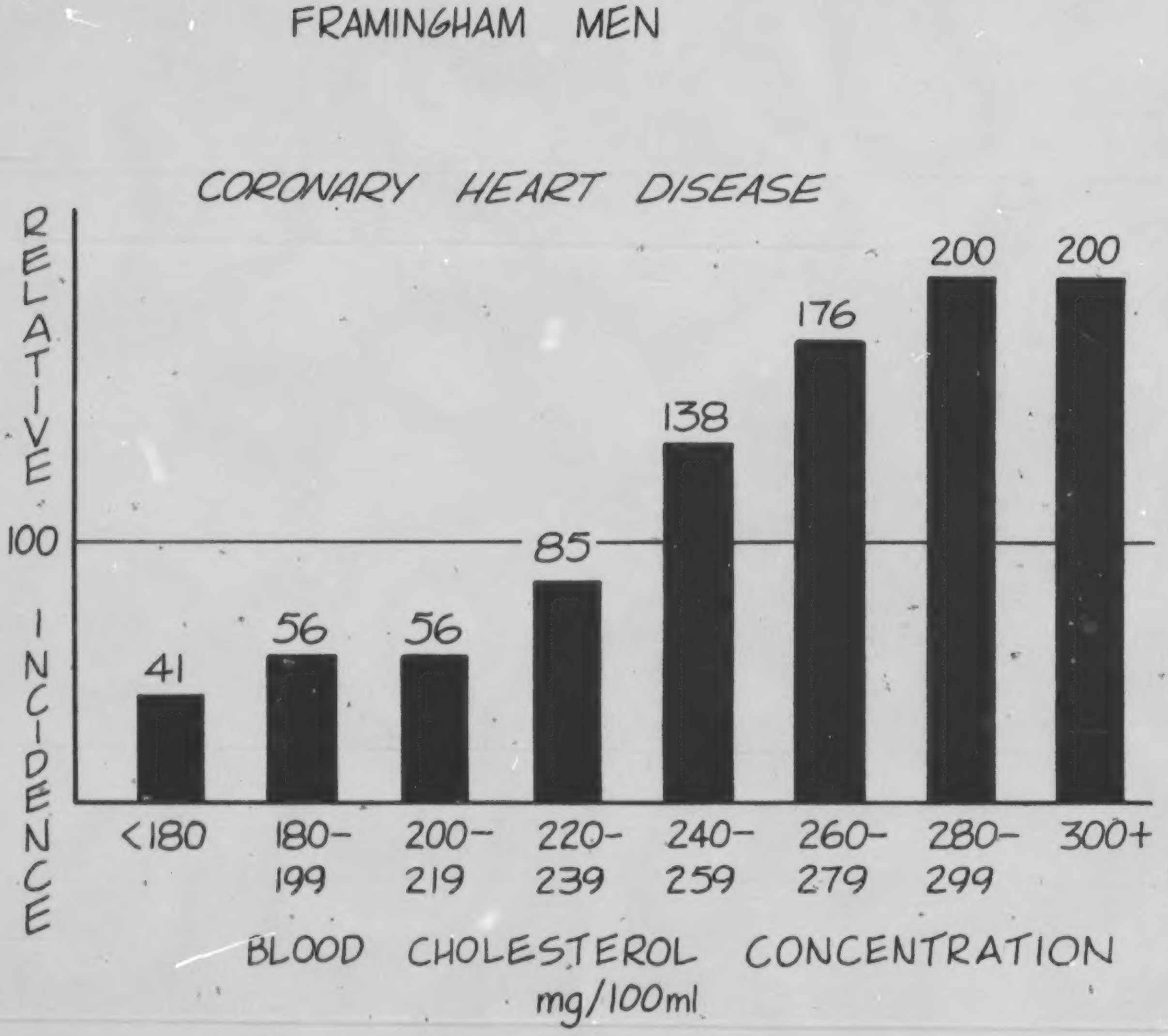
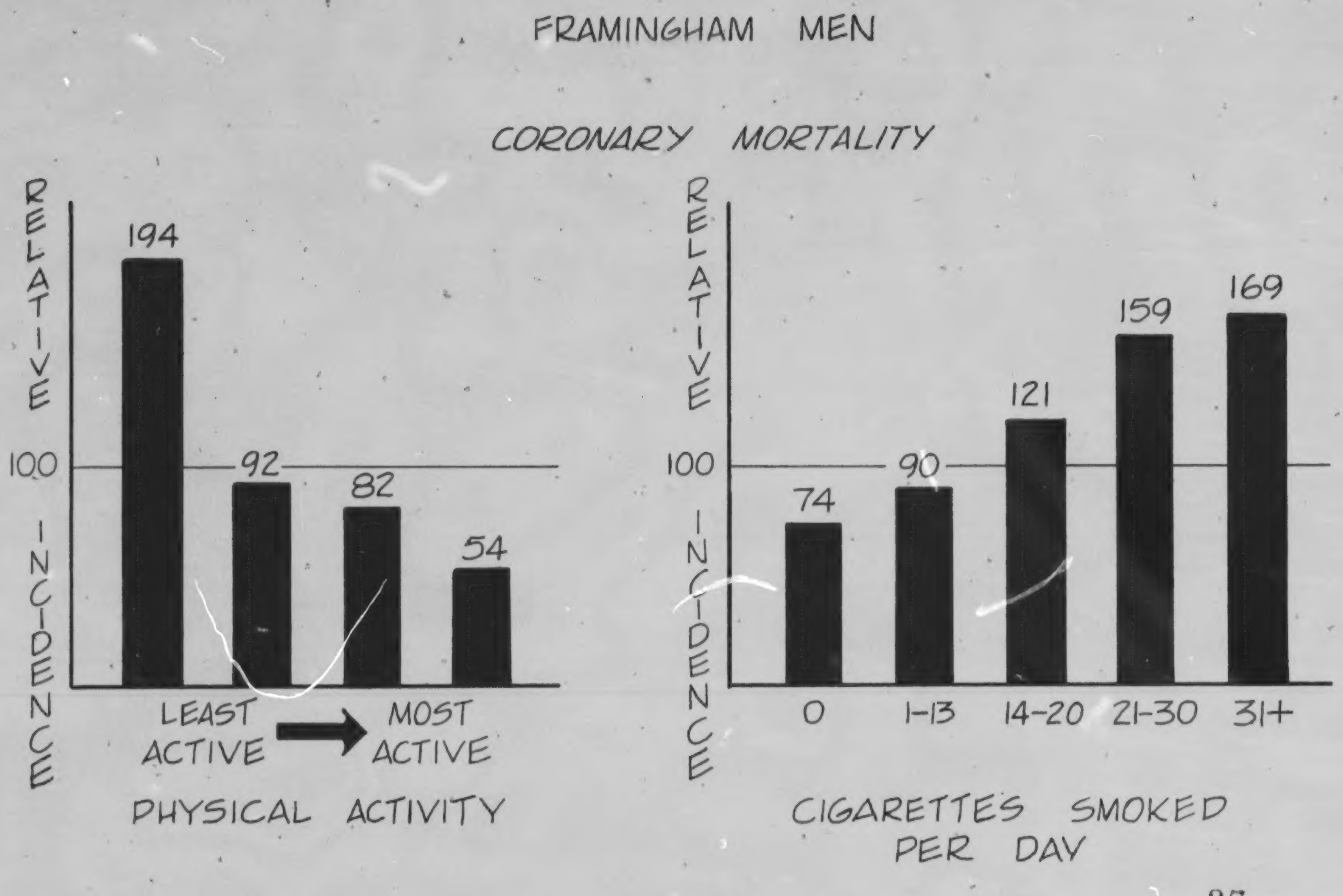

FRAMINGHAM MEN
CORONARY HEART DISEASE
RELATIVE INCIDENCE
100
41
56
56
85
138
176
200
200
<180
180-199
200-219
220-239
240-259
260-279
280-299
300+
BLOOD CHOLESTEROL CONCENTRATION
mg/100ml

FIGURE 2

FIGURE 3


FRAMINGHAM MEN
CORONARY MORTALITY
RELATIVE INCIDENCE
100
194
92
82
54
LEAST ACTIVE
MOST ACTIVE
PHYSICAL ACTIVITY
RELATIVE INCIDENCE
100
74
90
121
159
169
0
1-13
14-20
21-30
31+
CIGARETTES SMOKED PER DAY

INFORMATION ON ACTIVITY 2:

TEACHING NOTES:

1. The purposes of this activity are (1) to reinforce the nutritional calculations in Biomedical Mathematics, Unit II, Sections 9 through 22, and (2) to introduce the students to one of the main themes of the Science Unit--analysis of the diet. We will return to this theme in later science activities (Lessons 29 and 31) after the students have more background in nutrition.

2. Anticipated time: one to two periods.

3. It might be helpful to look up a few items with the class so students get the knack of using food tables.

4. Our calculations are based on the food tables in USDA Home and Garden Bulletin No. 72 (revised January 1971). If you use a different edition or a different reference book, your values will often differ from those given here.

5. Access to calculators will be helpful in this activity.

6. The calculations can be assigned as homework.

7. The activity can be shortened by eliminating one of the two diets. It can be extended by addition of additional 24-hour diets for analysis. In later lessons, the students will analyze their own diets.

8. It is a good idea to discuss this activity with the mathematics instructor and, if possible, to read mathematics Sections 9 through 22 (Unit II). If you don't have time to review the entire sequence, it is worthwhile at least to read Section 9. The students could apply vector techniques in their calculations if the math course has reached the appropriate point.

9. You may wish to emphasize that a nutritional analysis requires consideration of sex, age, weight and other factors. Also, point out that a diet analysis should be based on more than one day.

10. You may wish to point out that the two diets selected for analysis in this activity are not representative of good diets.

ANTICIPATED RESULTS:

See following tables and Teaching Note 4.

DIET A

Food	Food Energy (calories)	Protein (grams)	Fat (grams)	Carbohydrate (grams)	Meal
Pineapple	292.5	1.5	0	75	Breakfast
Egg	80	6	6	0	
Raisin Bread	130	4	2	26	
Butter	35	0	4	0	
Milk	160	9	9	12	
Boiled Ham	135	11	10	0	Lunch
Mayonnaise	100	0	11	0	
White Bread	140	4	2	26	
Potato Chips	115	1	8	10	
Orange	65	1	0	16	
Cookies	200	4	12	24	
Milk	480	27	27	36	
Pot-roasted Beef	245	23	16	0	Dinner
Mashed Potatoes	277.5	6	12	36	
Beans	15	1	0	3.5	
Milk	320	18	18	24	
Ice Cream	637.5	15	35	70	Snack
TOTALS	3427.5	131.5	172	358.5	

DIET B

Food	Food Energy (calories)	Protein (grams)	Fat (grams)	Carbohydrate (grams)	Meal
Candy	110	0	0	28	Snack (10:40 a.m.)
Cola	145	0	0	37	Snack (11:00 a.m.)
Candy	160	5	12	11	
Candy	115	1	4	21	Snack (1:00 p.m.)
Candy	145	2	9	16	Snack (2:10 p.m.)
Chicken	90	12	4	0	Evening Meal
White Bread	140	4	2	26	
Mashed Potatoes	277.5	6	12	36	
Corn	140	6	2	32	
Butter	70	0	8	0	
Peaches	75	1	0	20	
TOTALS	1467.5	37	53	227	

ANSWERS TO DISCUSSION QUESTIONS:

1. A food may have different nutritional values based on how it is processed or prepared. For example, white bread can be of the soft-crumb or hard-crumb types, and it may be sliced thin or thick. These differences result in different nutritional values.

2. The female diet (Diet A) included sufficient protein and more calories than needed. The male diet (Diet B) was insufficient in regard to calories and protein.

LESSON 3: (A) INTRODUCTION TO DIGESTION

(B) THE DIGESTIVE SYSTEM OF AN EARTHWORM

RATIONALE:

In this lesson the focus is shifted from the relation between diet and health to an introduction to the digestive system. In Section 2 the process of digestion and the anatomical structures involved are outlined. The basic concept of adaptation is introduced. In the laboratory, the digestive system of a live earthworm is examined.

OBJECTIVES:

The student will:

- list the principal nutrients (carbohydrates, fats, proteins).
- name and locate (e.g., on a drawing) at least three parts of the digestive tract that play a role in digestion.
- describe how the digestive tract is adapted to its function.
- compare the anatomy of the digestive tracts of an earthworm and a human.

SEQUENCE: ST-3; LA-3

SUGGESTIONS:

1. How did early investigators learn about the process of digestion? Two anecdotes could serve to stimulate discussion.

a. In the eighteenth century, the French chemist Réaumur experimented with his pet hawk. Meat was placed in metal tubes with screened ends and fed to the hawk. Réaumur wanted to determine whether the changes that occur during digestion are due to grinding or to some other process.

When the metal "cages" were regurgitated by his bird (a characteristic of hawks; they feed on small animals and regurgitate the skin and bones after digesting the "meat"), Réaumur was able to observe that the meat was partly digested--changes had taken place in the meat. The metal tube was unchanged. He concluded that the changes were not due to grinding.

b. In the nineteenth century, Dr. William Beaumont, an American military surgeon, learned about a hunter who had accidentally shot himself in the stomach. After healing, the wound had left a permanent opening through the abdominal wall and into the stomach. For ten years Beaumont fed the hunter and sampled the stomach contents through the "window." To Réaumur and Beaumont, we owe much of our early knowledge of the digestive process.

2. A tube or hose the approximate length of the digestive tract (25 feet) could provide a useful model to begin a discussion of the digestive system. At appropriate lengths, the various organs (in the form of paper mock-ups) could be attached. Questions to consider: How does a tube of this length fit inside our body? How does this crude model differ from a digestive tract?

3. A dissection of the fetal pig to show the digestive tract of a mammal would be a worthwhile demonstration. Another option would be to obtain part of the digestive tract of a cow or sheep from a slaughter house; directions for doing this are located in the Unit I Instructor's Manual, p. 33.

INFORMATION ON LABORATORY ACTIVITY 3:

TEACHING NOTES:

1. The primary purpose of this laboratory activity is to have the students observe first hand the digestive and circulatory systems of the earthworm. A secondary purpose is to give the students some experience in the art of dissection.

a. You may wish to discuss why dissection is important and how it relates to medicine. (See treatment in the introduction to the lab.) If you prefer, a fetal pig or mammalian dissection could be performed. You may need to be concerned about state laws regulating dissection.

b. Students who have qualms about or ethical objections to dissection could be given an alternate activity, such as a library reading exercise. Once students get going on a dissection (with some feeling for why they are doing it) they generally find it a very exciting and illuminating experience.

2. Anticipated time: one period.

3. It should be emphasized that when the earthworms are submerged in the alcohol solution they must be carefully observed to determine when they are sufficiently anesthetized for the dissection. If they are allowed to remain in the solution too long they will die. Also, if a worm is overly anesthetized, little or no peristalsis will be observed in the digestive tract and the pumping of blood through the aortic arches may be greatly diminished. If this happens, one

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thing you can do is rinse the worm once or twice with saline solution. This will usually remove sufficient alcohol to allow resumption of muscular contractions.

4. You may want to do a quick demonstration of how to open up an earthworm if your students have never done a dissection before. A filmstrip might be another good possibility.

5. The students are advised to put their worms back in the alcohol solution when they finish the dissection to avoid the possibility of the worm "coming to." This is a humane way of killing the worm and makes disposal easy for the instructor or assistant.

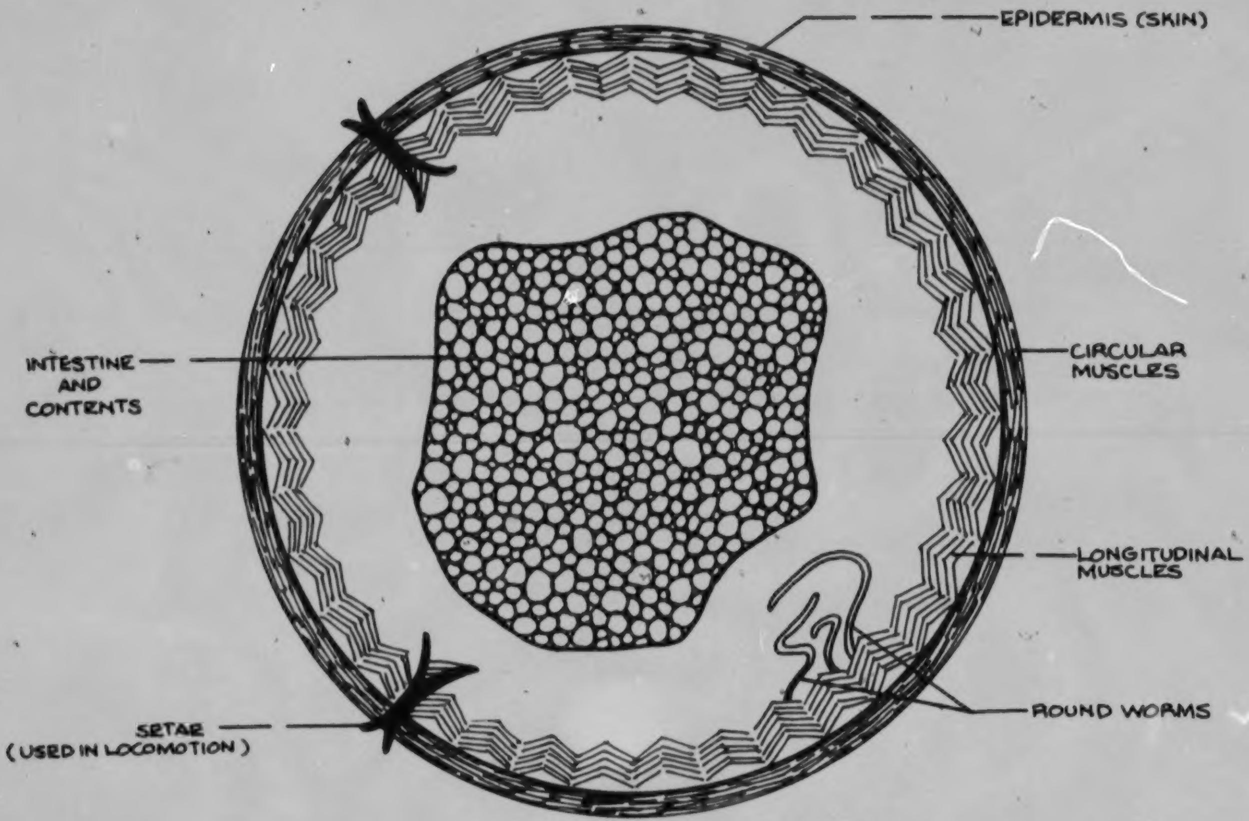
6. We suggest that the nightcrawler variety of earthworm be used because it is large enough to make dissection and observation fairly simple. These worms are readily available from biological supply companies. They should be ordered to arrive a day or so before the activity takes place. They may be kept in a container with moist earth and moss until needed. A few extra worms may be needed to allow for a demonstration before the students begin the activity or for possible errors during the activity.

7. If you wish to read more about the earthworm before the activity, or if any student is interested in obtaining more information, a suggested reference is Chapter 20 in Ralph Buchsbaum's Animals Without Backbones, University of Chicago Press, Chicago.

8. The directions call for a hand lens or a dissection microscope to aid in observation. The hand lens (or even the naked eye) is adequate for this activity, but good lighting is essential. A dissection microscope makes observation of the finished dissection very dramatic. If only one dissection microscope is available in the classroom, it may be set up to demonstrate hearts beating or the crop and gizzard contracting.

9. If there is sufficient time, students may wish to make a slide preparation of one of the segments, to observe the circular and longitudinal bands of muscles. The procedure is outlined below.

Using the mid-portion of the worm, which has not been opened up, cut off one segment using a sharp razor blade. Place the cross section on a slide and cover with a coverslip. To make the cross-section thinner, gently push down on the sides of the coverslip. Tape two sides of the coverslip down to maintain the pressure. Examine the walls of the cross section under the microscope. The students should be able to identify the circular and longitudinal bands of muscles. The arrangement of these bands is similar to that which occurs in the esophagus of man. You might ask the students to speculate on how these two groups of muscles work to move food through the digestive tract. Peristalsis will be treated in Section 5. The presence of small worms moving about within the cross section may also be noted. These are likely to be round worms and are very common inhabitants of soil, the earthworms' staple food. The students will encounter round worms later in this unit when they study parasitic diseases.


EPIDERMIS (SKIN)
INTESTINE AND CONTENTS
CIRCULAR MUSCLES
LONGITUDINAL MUSCLES
ROUND WORMS
SETAE (USED IN LOCOMOTION)

MATERIALS: (for 15 set-ups)

- 530 ml ethyl alcohol, denatured
- 32 g sodium chloride (NaCl)
- 20 live earthworms
- 15 dissection trays, wax bottom
- 150 to 200 straight pins
- 15 fine-tip scissors (must be clean and sharp)
- 15 forceps

15 razor blades
(must be clean and sharp)

15 dissection microscopes or
hand lenses

paper towels

15 beakers, 250-ml

15 compound microscopes

15 light sources

tape

15 microscope slides with
coverslips (optional)

PREPARATION OF REAGENTS:

25% ethyl alcohol, 2 liters: To 530 ± 10 ml of denatured ethyl alcohol, add 1470 ± 10 ml of water.

0.8% NaCl, 4 liters: Dissolve 32 ± 1 grams of NaCl in 4000 ± 50 ml of water.

ANSWERS TO PROCEDURE QUESTIONS:

1. The gizzard contracts rhythmically.

2. The gizzard's function is the grinding up of food using sand particles.

3. The folds increase the surface area of the intestine, thus increasing its absorptive capacity.

4. The movement resembles waves that sweep along the intestine. This is peristalsis. The function is to move nutrients and waste through this organ. The nutrients are absorbed through the intestinal walls and the waste is excreted upon reaching the anus.

5. There are five arches. The students should be able to locate at least four if they look carefully.

6. The arches contract rhythmically.

7. The arches contract and push blood out of the arches down the ventral blood vessel. Their function is to maintain a steady circulation of blood through the vascular system of the worm. They act as pumps analogous to the human heart.

8. The dorsal blood vessel also pulses with rhythmical contractions. These contractions push the blood returning along the dorsal blood vessel onward to the arches, where it is again pumped down into the ventral vessel.

ANSWER TO DISCUSSION QUESTION:

The digestive system of the worm is very similar to that of man, the primary differences being that the worm's mouth does not contain teeth and that the worm possesses a crop and a gizzard rather than a stomach. Also, the size of the worm's intestine is fairly uniform throughout its entire length, while man's intestine becomes wider in the last few feet (the large intestine or colon).

LESSON 4: (A) ENZYMES

(B) PROPERTIES OF THE ENZYME AMYLASE

RATIONALE:

Digestion consists of both mechanical and chemical processes. In this lesson the concept is introduced that small pieces of food need to be further reduced by chemical changes. The role of enzymes in these chemical processes and the unique properties of enzymes are described. In the following lessons, several different enzymes will be considered in relation to digestion. In the laboratory activity, the properties of amylase are investigated.

OBJECTIVES:

The student will:

- state the role of enzymes in digestion.
- describe the effects of catalysts on chemical reactions.
- contrast enzymes and non-biological catalysts.
- identify the suffix "-ase" as pertaining to enzymes.
- describe how an enzyme is affected by temperature and pH changes.

SEQUENCE: ST-4; LA-4

SUGGESTIONS:

1. A simple demonstration of catalysis might be used to start a discussion on enzymes and catalysis. For example, the breakdown of hydrogen peroxide is catalyzed by MnO_2. Hydrogen peroxide decomposes very slowly to water and oxygen.

$$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$$

But if manganese dioxide (MnO_2) is added to the hydrogen peroxide, the reaction proceeds at a much faster rate. The catalytic action of MnO_2 can be demonstrated as follows.

a. Into each of two test tubes, pour about 5 ml of 3% hydrogen peroxide.

b. Add a pinch of MnO_2 to one test tube. The reaction $2\ H_2O_2 \rightarrow 2\ H_2O + O_2$ will be greatly accelerated in this tube.

c. To demonstrate the increased amount of O_2 being given off from the tube to which MnO_2 has been added, place your thumb over the tube with the MnO_2

in it to allow O_2 to build up. Then perform the glowing splint test for oxygen. Repeat the procedure for the other tube.

2. The catalysis of hydrogen peroxide breakdown may also be demonstrated with liver extract to emphasize enzymatic catalysis. Hydrogen peroxide is a by-product of many chemical reactions that take place in our bodies. Because it is poisonous to us, our cells must break it down immediately. Therefore, we are equipped with an enzyme which performs the same function as MnO_2 did in the above reaction. This enzyme is found in abundance in the liver. Therefore, a simple demonstration of the biological catalysis of the above reaction may also be performed.

a. Place 2 ml of 3% H_2O_2 in a test tube.

b. Add a small piece (size of a rice grain) of the liver to the test tube and observe.

c. The procedure described above, using the glowing splint to demonstrate the generation of O_2, may also be used here.

The enzymatic decomposition of H_2O_2 has clinical significance and will be the basis of LA-6 (Detection of Blood in Simulated Stool).

3. LA-4 is designed to last at least two periods. You may wish to complete Parts I and II of the activity, then discuss ST-4. The labs may suggest questions for discussion. It may be best to defer Part III of the activity until after Section 4 is covered.

4. Part III of LA-4 is open-ended, but relatively simple. The intent is to encourage students to design their own investigation. Similar challenges of increasing complexity will be provided in later activities.

5. Students sometimes have difficulty comprehending the relative sizes of an enzyme and substrate, and the concept of an active site. Consider the following simulation which is simple and fun.

Use a ball-and-stick model to represent lactose (Figure 1). Then tell students that you are the enzyme, lactase, that breaks this molecule down. Emphasize the difference in sizes as representative of the size difference between many enzymes and substrates. You could color a black zone on one palm and a red

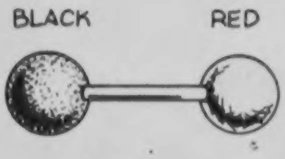


FIGURE 1: *Ball-and-stick model of lactose.*

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zone on the other corresponding to the model. Explain that these colored regions are "active sites"--regions of the enzyme that provide a surface complementary to the substrate--and that these active sites can fit the substrate in only one way (Figure 2). Any other position of you (the enzyme) and the model (lactose) would not provide a fit between active site and substrate and, therefore, would not work.

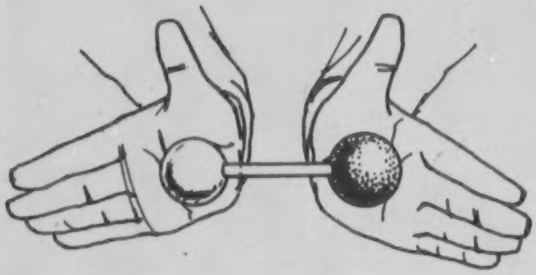


FIGURE 2: *Fit between active site and substrate.*

INFORMATION ON LABORATORY ACTIVITY 4:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to verify some of the statements made about enzymatic activity that appear in ST-4, namely, that the activity of an enzyme is affected by such variables as temperature and pH.

2. Anticipated time: two to three periods. (Each part of this activity takes at least a half hour.) Plan enough lab time so that students will not be stopped in the middle of any of the three parts.

3. The activity can be shortened by omitting one or more parts (e.g., Part II on temperature effects might be eliminated). It can also be shortened by omitting some of the variables. For example, in Part I, students could compare only two proportions of the substrate:enzyme; and in Part II students could compare the rate of starch breakdown at room temperature and only one other temperature.

4. The activity may be expanded by adding variables and assigning more open-ended activities, as in Part III. In addition, students could be required to prepare some of the reagents.

5. If you wish to save pH paper and time, the pH 5 and pH 9 solutions for Part III could be prepared in advance for the students. This would also reduce the amounts of 0.1 M HCl and 0.1 M NaOH needed.

6. If desired, saliva can be used in this activity as a source of amylase. However, the quantity necessary is not easily obtained. Also human saliva varies greatly in biological activity and therefore is unpredictable in a laboratory

activity. For these reasons we recommend using a simulated saliva solution. If you prefer to have the students use their own saliva, they will need to collect about 30 ml per team. This is then mixed with a equal volume of water and filtered through a double layer of cheese cloth. It should be stored in the refrigerator. Chewing a piece of Parafilm or clean rubber bands will help to cut down on the time necessary to collect the saliva.

7. Ideally each team should have access to two spot plates. If spot plates are not available they can be constructed by drawing heavy lines on glass plates with a glass-marking pencil. The pencil line will keep the solutions separate. If this is done, the glass plates should be placed on white paper so that the colors of the solutions can be seen easily.

8. The composition of the starch solution in this activity is of great importance. If you follow the directions given for its preparation, the amount of time necessary to complete the spot tests should be fairly consistent. If a starch solution of different composition is used, it may take more or less time to demonstrate starch breakdown.

9. The iodine solution must be added to the spot plate at the time the spot test is performed. If it is dropped onto the plates at the beginning of the checking period, the concentration of iodine will change due to evaporation. This will affect the results obtained when the test is finally run.

10. You may wish to point out to the students that the enzyme source is pig pancreatic amylase, rather than human saliva. The pig enzyme is readily available and is similar to the human enzyme in function.

11. In enzyme reactions, clean glassware is especially important. Traces of dirt or detergent may inhibit an enzyme.

12. Distilled water is not required to make up the solutions unless the tap water in your laboratory has a pH far from neutral.

13. Part III has been designed to encourage the students to solve problems. Because of the similarity of the problem in Part III to those solved in the rest of the activity, it is probable that the students can do all or much of the design themselves. However, you are in the best position to judge the capabilities of your class--you may wish to structure the activity differently. Possibilities include the following.

a. Have the students design and test a procedure. Allow them to make mistakes and then discuss the results. You might even have them redesign and repeat the activity based on this discussion.

b. Have the students submit a written procedure or outline for your evaluation before proceeding.

c. Have the students "brainstorm" on how they would design the procedure.

d. Provide the students with a procedure such as the one given in "Anticipated Results."

14. Since it requires time to transfer the solutions to the spot plates, the students will not be able to perform each test precisely at one-minute intervals. However, this will not significantly affect the results because the time lag involved should be fairly uniform for each one-minute test.

MATERIALS: (for 15 set-ups)

21.5 g sodium chloride ($NaCl$)
9.0 g potassium chloride (KCl)
1.8 g sodium bicarbonate ($NaHCO_3$)
9.0 g alpha-amylase (Sigma, #A6880, Type VI-A from hog pancreas)
15.0 g potassium iodide (KI)
7.5 g iodine (I_2)
8.0 g souble starch (e.g., "Niagara" instant laundry starch)
2.1 ml hydrochloric acid (HCl), conc.
1.0 g sodium hydroxide ($NaOH$)

90 test tubes, 16 x 125 mm
90 stoppers, cork #4
30 pipets, 10-ml
60 medicine droppers
15 test-tube racks
15 spot plates
15 glass-marking pencils
paper towels
clock with second hand

Part II Only:

30 beakers, 250-ml
15 thermometers
15 test-tube holders
10 lb ice
15 gas burners

15 ring stands
15 ring-stand rings
15 wire gauzes
matches

Part III Only:

pH paper, range 1-11

PREPARATION OF REAGENTS:

Simulated Saliva, 900 ml: Add 21.5 ± 0.1 g NaCl, 9 ± 0.1 g KCl and 1.8 ± 0.1 g of $NaHCO_3$ to enough water to make up 900 ml. Adjust pH with 0.1 M HCl or 0.1 M NaOH to 7.0. Add 9 ± 0.1 g of alpha-amylase and stir to dissolve. Store in refrigerator. Will keep for 3 days.

Iodine Solution, 900 ml: Dissolve 15 ± 0.1 g KI and 7.5 ± 0.1 g I_2 in 900 ml water. Store in brown bottle. Will keep for long periods.

Starch Solution, 800 ml: The preparation of starch is a critical part of the activity. To 8 ± 0.1 g soluble starch (e.g., "Niagara" instant laundry starch) add 800 ml boiling water. Stir to dissolve. Store in refrigerator. Will keep for 5 days.

0.1 M HCl, 250 ml: Add 2.1 ± 0.1 ml concentrated HCl to about 200 ml of water. Add water to total 250 ml.

0.1 M NaOH, 250 ml: Dissolve 1 ± 0.1 g NaOH in enough water to make 250 ml.

ANTICIPATED RESULTS:

PART I: EFFECT OF PROPORTIONS OF ENZYME AND SUBSTRATE ON RATE OF REACTION

S4 + A4: brown-black at 1 minute, yellow-black at 2 minutes and yellow-brown after 11 minutes.

S8 + A4: blue-black at 1 minute and yellow-black at 18 minutes. The reaction is not completed within 20 minutes. (At 20 minutes the color is still yellow-black.)

S4 + A8: blue at 1 minute and yellow-brown after 2 minutes.

Note: Although the above results indicate that the high proportion of enzyme to substrate works best, it should be made clear to the students that this situation does not normally exist within biological systems. In biological systems the proportion of enzyme to substrate is small.

PART II: EFFECT OF TEMPERATURE ON ENZYME ACTIVITY

Cold: blue-black at 1 minute, blue at 8 minutes and yellow-brown after 25 minutes.

Room Temp: blue-black at 1 minute, blue at 3 minutes and yellow-brown after 14 minutes.

Hot: blue-black at 1 minute and remains blue-black through the entire test.

Note: The most effective temperature was room temperature. Eventually starch was digested at 5 °C, but very slowly. This is the case because molecules move more slowly at low temperatures and react more slowly. There was no reaction in the "hot" solution because of enzyme denaturation.

PART III: EFFECT OF pH ON ENZYME ACTIVITY

SAMPLE PROCEDURE:

1. Label three test tubes "pH 5," "pH 7" and "pH 9." Label three more "A."

2. Add 4 ml of starch solution to the three tubes labeled with pH's.

3. Add 0.1 M HCl one drop at a time to the tube marked pH 5 until the starch solution gives a reading of pH 5 when tested with pH paper. Be sure to check the pH after each drop of HCl is added.

4. Add 0.1 M NaOH one drop at a time to the pH 9 tube until the starch solution gives a reading of pH 9.

5. Add 4 ml of simulated saliva (containing amylase) to all the tubes labeled "A."

6. Adjust one of the saliva tubes to pH 5 and another to pH 9.

7. Prepare a data sheet similar to the one below.

Time Elapsed	pH 5	pH 7	pH 9
1 minute			
2 minutes			
20 minutes			

8. Organize your data sheet, spot plates, droppers, etc.

9. At "Zero Time," combine the contents of one tube of simulated saliva solution with the appropriate tube of starch solution. Shake gently to mix and put a clean dropper in each tube.

10. When one minute has passed, place 4 drops of each mixture on the spot plate and add 1 drop of iodine solution. Mix by tapping or gently swirling the plate. Record the colors.

11. Repeat Step 10 once every minute for each reaction until the color changes to yellow-brown, or 20 minutes is up, whichever happens first.

ANTICIPATED RESULTS: The results will vary depending upon the procedure devised. When we performed the procedure given above the following results were obtained.

pH 5: remains blue-black throughout.

pH 7: same as Part II, room temperature.

pH 9: remains blue-black throughout.

ANSWERS TO DISCUSSION QUESTIONS:

1. Increasing the amount of substrate, while holding the amount of amylase constant, significantly increases the time necessary for the complete digestion of starch. Increasing the proportion of enzyme reduces the digestion time drastically.

2. When amylase is in a cold environment its enzymatic activity is greatly decreased.

3. A high-temperature environment destroys the catalytic activity of amylase. When enzymes are exposed to high temperatures, their structures undergo denaturation (a change which renders them inactive).

4. Salivary amylase is most active around pH 7.

5. One might expect the pH of the saliva under normal circumstances to be around pH 7. This could be tested by testing a sample of saliva with pH paper.

LESSON 5: DIGESTION IN THE MOUTH AND STOMACH

RATIONALE:

ST-5 discusses in detail the aspects of digestion which occur in the mouth, esophagus and stomach. ST-7 and ST-8 will complete the processes of digestion. There is no LA-5 since LA-4 is intended to extend over 2 to 3 periods. The activity on amylase (LA-4) was selected in part to coincide with the discussion of salivary amylase.

OBJECTIVES:

The student will:

- describe those processes of digestion which begin in the mouth.
- describe the functions of saliva in digestion.
- define peristalsis and explain its function.

- describe the most important function of the stomach.
- describe the biological function of reverse peristalsis.

SEQUENCE: ST-5

SUGGESTIONS:

1. The laboratory activity on amylase, LA-4, can be used to open discussion on digestion. One caution--the enzyme used in the activity was not salivary amylase but was derived from pig pancreas. Consequently, the optimal pH and other properties of that enzyme are not identical to those of the salivary enzyme.

2. A simple demonstration of the effect of amylase can be done by giving students unsalted crackers to chew. The crackers should be bland in flavor and the students should be told to (1) chew the cracker but not swallow it until the end of the demonstration, (2) record the initial taste and (3) record the taste after a minute or two. As the starch in the crackers is digested to simpler sugars, the students should be able to detect a change of flavor from bland to sweet.

3. You may wish to refer to a physiology textbook periodically as you present the lessons on digestion. Some useful references are listed in Lesson 1.

4. In discussing peristalsis, you may wish to refer back to LA-3, the earthworm dissection. Students probably saw peristalsis in the digestive tract.

LESSON 6: PEPTIC ULCER

RATIONALE:

ST-6 discusses the origin, nature, diagnosis and treatment of peptic ulcer, using the case-history approach. Peptic ulcer is a common medical problem related to the digestive process. It is the fourteenth most common cause of death in this country. In LA-6, the students will analyze for blood in the digestive tract. Such bleeding could be indicative of peptic ulcer as well as other conditions.

OBJECTIVES:

The student will:

- describe the symptoms of peptic ulcer.
- state how the stomach is protected from digestion by hydrochloric acid.

- define a psychosomatic condition.
- explain how blood is detected in stools.

SEQUENCE: ST-6; LA-6 (or reverse)

SUGGESTIONS:

1. LA-6 and ST-6 are closely related. Either one may be used to motivate the other.

2. The case history of Maria could be used to stimulate a discussion. It could be used to answer such questions as:

   What symptoms suggested an ulcer? Why?

   How did Dr. Miller confirm the diagnosis?

   What characteristics of Maria made her a good candidate for an ulcer?

3. Ulcers are so common that one or more of your students may have suffered from this condition. If so, perhaps they could contribute some personal experience to the discussion.

INFORMATION ON LABORATORY ACTIVITY 6:

TEACHING NOTES:

1. This activity introduces a procedure for the detection of blood in stool specimens. This complements the peptic ulcer case history in ST-6. The procedure is one used in many hospitals as part of the diagnosis of gastrointestinal bleeding. A positive result indicates the presence of lesions somewhere in the digestive tract. Other confirmative tests must be made before a specific diagnosis can be reached.

2. Anticipated time: one period.

3. The quantities of blood added to the four simulated stool samples provide results ranging from "negative" to "very heavy bleeding" so that adequate comparisons can be made by the students.

4. Fresh blood is preferred for this activity. It can be obtained from a hospital medical laboratory. Request that the blood be citrated. Alternative directions are included for the use of blood from raw beef.

5. o-tolidine carries a cautionary label. By law, the entire family of aniline drugs must warn that they may be carcinogenic. In reality, casual brief

contact with this substance is relatively harmless. Spills on the skin should be washed off with soap and water. Other spills should be carefully cleaned up with absorbent material.

6. The tares used in Procedure Step 2 should be bond or other hard-surfaced paper to minimize absorption of the stool samples.

MATERIALS: (for 15 set-ups)

- 20 g each of four simulated stool samples
    - 20 g cornstarch
    - 20 g cornmeal
    - food coloring (red, green and yellow)
    - 1.5 ml blood
- 60 ml acetic acid, glacial
- 0.8 g o-tolidine, reagent grade, (MCB TX705)
- 400 ml ethyl alcohol, denatured
- 50 ml hydrogen peroxide solution, 3%
- 60 test tubes, 16 x 125 mm
- 15 graduated cylinders, 10-ml
- 15 medicine droppers
- 15 balances
- 15 test-tube racks
- 60 stoppers, cork, #4
- 15 glass-marking pencils
- 60 toothpicks

PREPARATION OF REAGENTS:

Simulated Stool Samples: Combine 20 g cornstarch with 20 g cornmeal. Mix by stirring. In a second container, combine 25 ml tap water, 24 drops (1.2 ml) red food coloring, 8 drops yellow food coloring and 12 drops green food coloring. Add the colored water to the mixture of cornmeal and cornstarch. Stir to mix thoroughly. Divide into four equal parts (about 20 g each), and place in four containers labeled A, B, C and D. Add whole blood as indicated.

Sample A: 1 drop

Sample B: 1 ml

Sample C: 6 drops

Sample D: no blood

Adjust the samples to the desired consistency by adding either water or cornstarch in small amounts. Cover the samples and store under refrigeration for up to 3 days.

Alternative to whole blood: Snip, using scissors, 4 oz beef liver, and allow to stand for 30 minutes. This should provide at least 3 ml of blood. Since the beef blood has not been citrated while still fresh, its peroxidase activity should be somewhat less than that of fresh, citrated whole blood. For this reason, use twice the volumes indicated for whole blood. In addition, it may be necessary to instruct the students to allow their samples to stand for 10 to 20 minutes before recording their results (Procedure Step 8).

Acetic Acid Solution: Add 60 ml glacial acetic acid to 240 ml of water. This solution is stable indefinitely.

o-tolidine Solution: Dissolve 0.8 g reagent grade o-tolidine in 400 ml of denatured ethyl alcohol. The solution is stable for 30 days if refrigerated. (Please note: Inferior grades of o-tolidine produce less marked results.)

ANTICIPATED RESULTS:

	COLOR	GRADE
Sample A	faint green	1
Sample B	dark blue-green	4
Sample C	light to medium blue-green	2-3
Sample D	no color	0

ANSWERS TO DISCUSSION QUESTIONS:

1. Since the amounts of o-tolidine and hydrogen peroxide in each tube are the same, the reaction in each test tube containing blood should proceed to the same endpoint, i.e., the final result for each sample containing peroxidase should be a dark green color. Peroxidase is not used up in the reaction since it is an enzyme. Consequently, different amounts of peroxidase affect only the rate of the reaction.

2. Meat contains blood and the blood contains peroxidase. The test might give a positive result, even though no lesion is present.

3. To determine whether bleeding is intermittent or continuous. The results of a single test may be misleading.

LESSON 7: (A) DIGESTION IN THE DUODENUM

(B) ANALYSIS OF GALLSTONES FOR BILIRUBIN

RATIONALE:

In this lesson we return to the digestive process, continuing from where we left off in Lesson 5. This lesson focuses on the duodenum, the liver, the gallbladder and the pancreas--organs of critical importance to digestion. LA-7 gives the students experience with a qualitative test for bilirubin in gallstones.

OBJECTIVES:

The student will:

- identify those nutrients that are digested in the duodenum.
- describe the roles of the liver, gallbladder and pancreas in digestion.
- explain the role of bile in digestion.
- define a hormone and give one example of how hormones aid in digestion.
- describe a qualitative test for bilirubin in gallstones.

SEQUENCE: ST-7; LA-7

SUGGESTIONS:

1. Step 6 of the procedure of LA-7 calls for a 30-minute waiting period. You may wish to use that time for discussing Student Text or LA-8. At any rate, it will be necessary to plan the activity so that there will be at least 30 minutes time available after Step 6 is performed.

2. The students may be interested in the etymology of the term "duodenum." The word "duodenum" is derived from a Latin word meaning "twelve fingers each," a reference to the fact that the length of the organ is about the same as the width of twelve fingers.

3. You may wish to expand on the role of hormones in the body since they are so important in human physiology. See Background Information.

4. You can refer to foods to illustrate the nature of an emulsion and an emulsifying agent. Some examples of emulsions are mayonnaise and homogenized milk. Oil and vinegar salad dressing is not an emulsion; after mixing it will separate into layers. But you can demonstrate how to make an emulsion with oil and vinegar. Mix about 20 ml of vinegar with about four times as much salad oil. They will

separate into two layers. Then beat an egg into the mixture. After beating, the various components will not separate out into layers because the egg contains emulsifying agents.

BACKGROUND INFORMATION ON HORMONES:

The term "hormone" comes from a Greek word meaning "to stir up" or to excite. Hormones generally serve as messengers or regulators. The play important roles in most homeostatic systems in the body.

Hormones vary in chemical structure. Many are polypeptides or small proteins. Examples of such hormones are insulin, growth hormone and oxytocin (stimulates milk production in females). Thyroxin is an example of a hormone that is an amino acid. Steroid hormones are made from cholesterol. Examples of steroid hormones are the sex hormones and cortisone. An interesting class of hormones that is under scrutiny are the prostaglandins. These substances are complex polyunsaturated fatty acids. The prostaglandins perform a variety of functions such as lowering the blood pressure and stimulating the smooth muscles. Of particular interst in the context of this unit on nutrition is that prostaglandins are made from arachidonic acid. Arachidonic acid is one of the essential fatty acids. In has been suggested that prostaglandins may have clinical implication for treatment of several diseases including heart disease and asthma.

An imbalance of hormones is associated with a number of diseases as shown in the table on the following page.

Of special interest in the context of nutrition are the digestive hormones. Gastrin, for example, is a polypeptide hormone produced in the stomach lining. It causes secretion of pepsinogen and HCl. Secretin is another polypeptide hormone. It is produced in the duodenum, released to the blood stream, and causes the pancreas to secrete water and bicarbonate into the duodenum, thus neutralizing the acidic material entering the duodenum from the stomach. Cholecystokinin is another digestive hormone produced in the upper intestinal mucosa. It causes the gallbladder to contract and release bile.

HORMONE	DISEASE	COMMENTS
thyroxin	goiter	insufficient iodide in the diet, low BMR (Section 19)
	cretinism	retarded growth, mental retardation, genetic defect (Section 26)
	hyperthyroidism	activity of thyroid too high, high BMR (Section 26)
insulin	diabetes mellitus	high blood sugar, high rate of urine production (Sections 24 & 32)
adrenal cortex hormones	Addison's disease	insufficient hormone production; loss of weight, weakness, low blood sugar
growth hormone	hormonal dwarfism	insufficient hormone production; physical retardation
	acromegaly	excess hormone production; enlarged hands and feet, distorted facial features
adrenocorticotropic hormone (ACTH)	Cushing's disease	too much adrenal contex hormone due to excessive ACTH production; muscle degeneration, brittle bones, high blood pressure

INFORMATION ON LABORATORY ACTIVITY 7:

TEACHING NOTES:

1. In this activity and the next one the students will perform a qualitative and a quantitative test on gallstones for bilirubin. The purpose of these activities is three-fold:

a. to give the students a chance to work with a clinical specimen, a gallstone;

b. to provide the students with an opportunity to perform an analytical test that they might do if they worked in a clinical pathology laboratory; and

c. to stress the difference between quantitative and qualitative tests in biomedicine.

2. Anticipated time: one period.

3. For both instructional and motivational reasons, it is desirable that the students work with authentic gallstones. It should be possible to obtain gallstones through the clinical pathology laboratory of your local hospital. Operations for gallbladder and stone removal are common, so that procuring 3 or 4 gallstones for the activities should present no problem. You might request that if possible you be supplied with a few stones of orange color, since this color is usually due to the presence of bilirubin.

4. Two samples of ground-up gallstone are called for. One sample should be derived from one of the gallstones. Pick a relatively large one since you will need enough ground-up sample for use in this activity and the next, where the quantitative analysis is performed. The second sample is simulated, and contains only calcium carbonate. The reason for incorporating one simulated sample is to add an element of discovery to the activity by insuring that there will be at least one negative result in the testing. Since stones that do not contain any bilirubin are very rare, this sample is simulated. Instructions on how to prepare the sample are included below. If you are unable to obtain a real gallstone, you could use two simulated samples. Relevant instructions are included below.

5. The 4 ml of bilirubin-detection reagent described in Procedure Step 4 is sufficient for two students, each performing two tests.

MATERIALS: (for 30 set-ups)

3 to 4 gallstones
1.25 g sulfanilic acid
15 ml hydrochloric acid (HCl), conc.
10 g sodium nitrite ($NaNO_2$)
100 mg bilirubin
10 to 20 g calcium carbonate
400 ml methyl alcohol
2 mortars and pestles
150 test tubes, 16 x 125 mm, Pyrex
30 scoopulas
15 graduated cylinders, 10-ml
30 small funnels
15 test-tube racks
60 rubber stoppers, #0
15 glass-marking pencils
30 pipets, 1-ml, and rubber bulbs
15 balances
60 filter papers, Whatman No 1, 11 cm

PREPARATION OF REAGENTS:

Bilirubin-detection reagent: (This reagent is also to be used in Activity 8).

Solution A: Dissolve 1.25 ± 0.01 g sulfanilic acid in 15 ± 1 ml of conc. HCl and dilute by adding to 235 ± 5 ml of water.

Solution B: Dissolve 10.0 ± 0.1 g of sodium nitrite in water and dilute to 50 ± 1 ml. Store in refrigerator. Will keep up to 4 weeks.

Reagent: Take 1.0 ± 0.01 ml of Solution B and dilute to 10 ± 0.1 ml with water. Add 100 ± 1 ml of Solution A to 3.0 ± 0.1 ml of dilute Solution B. Mix. This reagent should be used within 30 minutes after preparation.

Gallstone mixture: The table that follows gives instructions on how to make up the gallstone samples. If a real gallstone is used as Sample #1 in this activity and is found to contain bilirubin, the remainder should be saved for use in LA-8. If gallstones are not available, then both samples in LA-7 will have to be simulated. Calcium carbonate is used as a filler in the simulated samples. It may cause bubbling when acidic reagents are added. However, this should not be a problem since bubbling will not interfere with the color reaction.

TABLE: COMPOSITION OF GALLSTONE SAMPLE

SAMPLE	REAL GALLSTONE	CALCIUM CARBONATE	BILIRUBIN
Sample #1	10 g	---	---
Sample #1, simulated	---	10 g	.1 ± .01 g
Sample #2, simulated	---	10 g	---

SPECIAL NOTE: The simulated gallstone mixtues may be made up in advance except for the one containing bilirubin. Bilirubin is unstable and is converted to biliverdin which does not react with the color reagent used. Therefore, in the case of Simulated Sample #1, bilirubin should be added to the mixture just before it is to be used.

ANTICIPATED RESULTS:

The results for real gallstones should be positive since most stones contain bilirubin. If Sample #1 is simulated, a positive test for bilirubin should result. Simulated Sample #2 will give a negative result.

ANSWERS TO DISCUSSION QUESTIONS:

1. The test done for bilirubin is qualitative because it gives only a positive or negative result indicating the presence or absence of bilirubin in the sample. A quantitative test would give results indicating how much bilirubin was present, if any.

2. This test could be converted to a quantitative one by measuring the intensity of the color with a colorimeter and then determining the concentration of bilirubin present from a standard calibration line made by testing samples of known bilirubin concentration. (This, in effect, is what will be done in LA-8.)

LESSON 8: (A) DIGESTION AND ABSORPTION IN THE INTESTINES
(B) QUANTITATIVE ANALYSIS OF GALLSTONES FOR BILIRUBIN

RATIONALE:

In this lesson the digestive and absorptive processes which occur beyond the duodenum are discussed. Most of digestion and absorption occurs in the small intestine. In the laboratory, the students perform a quantitative analysis for bilirubin. Since this activity follows a qualitative analysis of bilirubin, the two activities illustrate the distinction between qualitative and quantitative analyses.

OBJECTIVES:

The student will:

- describe the digestive events that occur in the small intestine.
- explain the role of villi in absorption.
- state which nutrients are absorbed into the blood and which into the the lymphatic system.
- define appendicitis and describe how it is treated.
- summarize the digestive processes, from the mouth to the large intestine.
- explain the difference between qualitative and quantitative analyses.
- describe how bilirubin is analyzed for by colorimetric techniques.

SEQUENCE: LA-8; ST-8

SUGGESTIONS:

1. Structurally, villi are well adapted to the function of absorption. The structure-function relationship is a recurrent theme in this course and merits emphasis. If you have slides of the intestinal wall, they should show what villi look like. Also, if you have access to a fetal pig or other source of small intestine, the students could observe villi through the microscope.

2. Appendicitis is a common medical problem, and one or more students may have personal experiences to contribute. You may wish to amplify the brief discussion of appendicitis with reference to the following Background Information.

BACKGROUND INFORMATION ON APPENDICITIS:

Appendicitis should be of medical interest to high school students because over 30% of all cases occur between the ages of 11 and 20 with the peak frequency being about age 15. And appendicitis is fairly common. An average-sized community hospital can be expected to care for about 100 cases annually.

Appendicitis is the acute inflammation of the appendix due to bacterial infection. The cause is not always known but is often felt to be the retention of something in the appendix. Whatever the precipitating cause, once started the inflammation tends to progress. Without surgical or antibiotic intervention, the appendix may rupture, and fatal peritonitis may result.

The first symptom is usually abdominal pain. Although the appendix is located in the right abdominal region, the initial crampy pain need not be at the same point. Fever, if present, is almost always low grade (under 38 °C). Another early symptom is loss of appetite, and in about half of the cases nausea is present. After 2 to 24 hours the initial pain subsides, but a more persistent and "heavier" pain localizes in the region of the appendix, usually at what is known as McBurney's point, which is near the base of the appendix. A careful examination will usually reveal the following early signs of peritoneal irritation.

1. Tapping over the tender area will be painful.

2. The abdominal muscles will be slightly more tense on the right side than on the left--especially on gentle pressure.

3. Coughing may cause the pain to worsen momentarily.

If the examiner suspects appendicitis, usually the patient will be observed very closely. The commonest laboratory study is a white blood cell and differential blood cell count. Most cases of appendicitis will show an increase in total white blood cells and/or an increase in the proportion of polymorphonuclear cells (PMN's or neutrophils).

If the probability of early appendicitis is high, surgical exploration is recommended. Doubtful cases are medically observed. In women, the diagnosis may be more difficult because right ovarian bleeding at ovulation and pelvic inflammatory disease may cause similar symptoms.

During the observation period, food must not be consumed and pain killers or laxatives must not be given. Rupture with subsequent peritonitis is uncommon in the 11- to 20-year age group but is common in very young or old patients.

Mild appendicitis sometimes subsides spontaneously. Unfortunately, a recurrence (if it occurs) is likely to be more difficult to diagnose. For this reason (and others) antibiotics should not be used until a definite diagnosis can be made.

INFORMATION ON LABORATORY ACTIVITY 8:

TEACHING NOTES:

1. In this activity the analysis of gallstones for bilirubin is continued. This time a quantitative test is performed to determine the concentration of bilirubin in the samples that gave a positive reaction for the qualitative test performed in LA-7.

2. Anticipated time: one to two periods (including waiting time).

3. You may wish to review the procedure for setting up the BIP and test well for colorimetry and standardize the instrument with the blank while the students wait for the bilirubin reaction to occur. The absorbance-transmittance table appears on the inside rear cover of the Laboratory Manual.

4. The colorimetry reading is this activity should be made from 30 to 40 minutes after the reagent is added to provide time for the development of a stable color.

5. If a real gallstone was used in LA-7 and found to contain bilirubin, this same stone should be used for the quantitative analysis. If this was not the case, a simulated sample will do. Such a sample can be prepared using the instructions given for simulated sample #1 in the information on LA-7. The sample should be prepared immediately before it is used.

MATERIALS:

gallstone used in LA-7
6 ml hydrochloric acid (HCl), conc.

100 mg bilirubin
10 g calcium carbonate ($CaCO_3$)
} (optional)

bilirubin-detection reagent (from Solutions A and B prepared for LA-7)
750 ml methyl alcohol
2 mortars and pestles
120 cuvets, 16 x 125 mm, Pyrex
60 rubber stoppers, #0
30 scoopulas
15 graduated cylinders, 10-ml
30 small funnels
15 test-tube racks
15 glass-marking pencils
30 pipets, 1-ml, and rubber bulbs
15 balances
60 filter papers, Whatman No. 1, 11 cm
10 BIP colorimeters

PREPARATION OF REAGENTS:

Bilirubin blank: Dilute 6 ± 0.1 ml of conc. HCl by adding it to 94 ml of water.

ANTICIPATED RESULTS:

The results will vary depending upon the gallstone used. We obtained a result of 0.76 mg of bilirubin per 100 mg of gallstone analyzed. In a simulated sample prepared as described in the information on LA-7, the amount of bilirubin in 100 mg of sample should be about 1.0 mg.

ANSWERS TO DISCUSSION QUESTIONS:

1. The concentration of bilirubin is determined by dividing the value obtained from the graph by 10, since the total volume of the sample solution was 10 ml rather than 100.

2. One of the principles employed when making up blanks for colorimetry is that the blank should contain all the same components used to make up the reagent tube, except for the active ingredient in the reagent. Thus the reaction between the chemical being analyzed for and the reagent only occurs in the reagent tube and the difference in transmittance readings can be directly attributed to this chemical reaction.

3. To obtain a graph relating absorbance to standard known concentrations of bilirubin one would prepare a series of solutions containing known concentrations of bilirubin. Then a sample of each of these solutions would be tested with the bilirubin-detection reagent and the % T measured with the colorimeter. The % T readings are then converted to absorbance values and a graph is drawn relating the absorbances to the bilirubin concentrations of the solutions tested.

4. If the color reaction is so intense that the transmittance reading is too low for the colorimeter, then the solution must be diluted to bring it within

the desired range. The concentration of the original solution is found by multiplying the result obtained by the dilution factor used.

5. The sources of error in this analysis include:

a. error in all mass and volume measurements;

b. loss of some of the solution during filtration, making the actual volume of the test solution on which the final calculations are based slightly less than 10 ml;

c. error in the standard graph;

d. error caused by using a standard graph based on a single colorimeter to interpret data obtained with other colorimeters;

e. incomplete extraction of the bilirubin so that some of it was not dissolved and thus did not take part in the color reaction;

f. errors made in standardizing the colorimeter and in reading the transmittance when testing the samples.

LESSON 9: (A) DISORDERS OF THE DIGESTIVE TRACT
(B) REVIEW

RATIONALE:

In this lesson some of the more common diseases and ailments of the digestive tract are considered. The focus on medical problems serves, in part, to review the sequence of lessons on digestion. There is no laboratory activity scheduled, since a review of the digestion sequence is intended.

OBJECTIVES:

The student will:

- explain the difference between the two forms of viral hepatitis.
- define and list the symptoms of gallstones and pancreatitis.
- identify the most common cause of recurrent indigestion.

SEQUENCE: ST-9

SUGGESTIONS:

1. A brief reference is made to immunology in ST-9. You may wish to expand on this topic. However, part of Unit III will be devoted to this subject.

2. The results of the two laboratory activities on gallstones may be reviewed in relation to Section 9-2 on gallstones.

3. It is likely that Section 9-4 will strike a familiar chord in most students because minor gastrointestinal disorders are so common. The treatment in the Student Text emphasizes the relation between psychology and disorders of the digestive tract. You may wish to discuss this material with your colleague in Biomedical Social Science.

You might suggest to the students the task of watching one or more TV commercials on drugs and GI disorders. Students can report on what was said and evaluate the commercials in the light of Section 9-4.

4. Between Lessons 9 and 10 would be an excellent time to review and give the students a quiz.

KEY--REVIEW SET 9:

1. Whereas man once grew or gathered his own food, through time the production (and even preparation) of food has been centered in fewer individuals. The need for food preservation has created problems in such areas as loss of nutrients, safety of additives, etc.

2. The Framingham study indicated a relationship between high blood-cholesterol level and heart disease. The blood-cholesterol level is, in turn, related to diet.

In North Kyrelia, Finland, there is an unusually high rate of heart disease. The prevalence of this disease is associated with a diet rich in the kind of fats that can be converted to cholesterol.

Other studies have shown that dietary salt is also related to heart disease. Finally, obesity increases the risk of heart disease.

3. In the process of digestion, the proteins and carbohydrates in food are changed to small and soluble substances which can pass into the bloodstream through the walls of the intestines. This is accomplished by mechanical processes (such as chewing) and chemical processes (through the action of enzymes and other body chemicals). Fat digestion products are relatively insoluble in water and are transported mainly by the lymphatic system.

4. Mouth, esophagus, stomach, duodenum, small intestine, large intestine.

5. An enzyme is a biological catalyst. Enzymes speed up the reactions of digestion without being altered in the process.

6. If the teeth were missing food would have to be cut up into small pieces to make it possible to swallow it, and to increase the surface area available to the digestive enzymes.

7. The stomach secretes a protective mucus. In addition, the cells that line the stomach are repaired at a rapid rate. Finally, hydrochloric acid is normally not secreted in quantity except when food is in the stomach.

8. The liver produces bile which breaks down fat. Bile is stored and released by the gallbladder. The pancreas secretes a digestive juice which contains enzymes necessary for the breakdown of proteins, fats and carbohydrates.

9. The villi provide a great deal of surface area through which molecules may be absorbed.

10. Epidemiological evidence is gathered from studies of the traits and habits of individuals in large population samples. Biological evidence is data on the biological properties of the biosystem being studied. Biological studies usually involve small populations and are carried out in more carefully controlled environments, such as research laboratories.

11. This question was included inadvertently. The topic of excessive salt intake and its relation to health is taken up in a later section.

12. The stomach serves mainly as a storage depot for food, passing it on to the duodenum as required. The HCl secreted in the stomach also kills most bacteria that enter the digestive tract, dissolves some minerals and continues the breakdown of large particles of food into smaller ones. A small amount of protein is digested by pepsin and a limited amount of carbohydrate digestion also occurs in the stomach.

13. Sometimes. Gallstones may block the pancreatic duct causing a backup of enzymes in the pancreas, where they become activated and cause inflammation. Gallstones may also block the common bile duct. In this case, pancreatitis may result from bile entering the pancreas.

14. The small intestine is more important since this is the region in which most digestion occurs. The large intestine is primarily responsible for the absorption of water from the residue of the digestive process.

LESSON 10: WATER--AN UNUSUAL NUTRIENT

RATIONALE:

Water is one of the most crucial nutrients in life yet it is often taken for granted. A great percentage of the mass of living organisms is water. Lesson 10 suggests some answers to the question, "Why water and not some other substance?" Some important properties of water (such as heat capacity) are explained in terms of hydrogen bonding.

OBJECTIVES:

The student will:

- list at least three unusual physical properties of water.
- explain how the distribution of charge in a water molecule leads to hydrogen bonding.
- explain how hydrogen bonding is responsible for at least two unusual physical properties of water.
- describe at least three sources of the body's water and at least three ways in which water is removed from the body.
- explain the difference between inorganic and organic chemistry.
- describe how the heat capacity of a liquid can be determined in the laboratory.

SEQUENCE: ST-10; LA-10

SUGGESTIONS:

1. ST-10 is written in such a way as to encourage the students to recognize water from a description of its unusual physical properties. The problem is not difficult, but it may get the students to think about what they're reading.

2. It may be a good idea to discuss the importance of water in human history--civilizations have almost always begun near major waterways or oceans; most of the world's population is still either near an ocean or near a major waterway; wars have been fought over access to water.

3. Another approach that may appeal is to point out that several popular theories of the origin of life involve the primitive ocean (for examples refer to Oparin's books on the origin of life). In the same vein, exobiologists often assume water on a planetary body is a prerequisite to life.

4. One unusual property of water that is critical to life and can be used for a simple classroom demonstration is solubility. Nutrients must be dissolved to enter the bloodstream in quantity. For a demonstration, you could add equal amounts of a nutrient such as sugar, a soluble amino acid, sodium chloride or vitamin C to test tubes containing equal molar quantities of solvents. For example, compare solubility in water and ether or benzene.

5. In LA-11 the students construct molecular models of water. You may wish to make use of models to help explain hydrogen bonding.

INFORMATION ON LABORATORY ACTIVITY 10:

TEACHING NOTES:

1. This activity introduces a simple method for the determination of the heat capacity of a liquid. The heat capacity of water is compared to that of two other common liquids, ethylene glycol (antifreeze) and cooking oil. The activity reinforces ST-10, which discusses some of the unusual properties of water. In addition, the activity provides the first exposure to calculations involving energy (calories) in Biomedical Science.

2. Anticipated time: two periods. The activity may be shortened or lengthened by omitting or adding other compounds. When selecting substances, remember that many organic liquids are flammable or toxic and should be avoided.

3. It may be desirable to discuss the calculations before beginning the activity. In particular, the students may have difficulty distinguishing between the units for heat and temperature. As an example of the distinction between heat and temperature, you might wish to explain that one gram of ice at 0 °C requires 80 calories in order to change into one gram of water at 0 °C. Although heat has been added to the system, the temperature has not changed.

4. You can save time and work by having the students crush their own ice. If an ice crusher is not available, the ice may be placed inside two or three layers of plastic bags (or a cloth bag) and crushed with a mallet or hammer. If an electric ice crusher is used, take care not to overheat the motor. In general, the results are improved if the ice is rather finely crushed.

5. The quantities of ethylene glycol and cooking oil specified in the materials list assume that half of the class tests the first liquid while the other half tests the second. The liquids may then be re-used by other groups so that each group has a chance to test all three liquids.

6. The students should be warned that the hot 125-ml flask used in Procedure Step 4 should not be touched with their fingers. Instead, a paper towel or a cloth should be used to prevent burns.

MATERIALS: (for 15 set-ups)

- 900 ml ethylene glycol (1 qt of a commercial antifreeze is sufficient)
- 900 ml cooking oil (1 qt is sufficient)
- 30 Erlenmeyer flasks, 125-ml
- 15 stoppers, rubber, #5 (or cork, #12)
- 15 gas burners
- 15 ring stands
- 15 ring-stand rings
- 15 wire gauzes
- 30 styrofoam cups (15 of these must be 12-oz)
- 15 beakers, 250-ml
- 15 beakers, 150-ml
- 5 pounds crushed ice
- 15 thermometers
- 15 scoopulas
- 15 balances
- containers suitable for storing used oil and ethylene glycol

ANTICIPATED RESULTS:

SUBSTANCE	MEASURED HEAT CAPACITY in (cal/g-deg)
water	.85-.95
ethylene glycol	.65-.75
cooking oil	.60-.70

The actual value for the heat capacity of water is 1.00 ± .003 cal/g-deg over the range of temperature used in the activity. The discrepancy between measured and actual values is attributable to the unsophisticated techniques used in the procedure (see answer to Discussion Question #2).

The actual values for ethylene glycol (antifreeze) and cooking oil range between .50 and .70 cal/g-deg. Precise values are difficult to establish for the following reasons.

1. Both antifreeze and cooking oil are mixtures of a number of substances. Consequently, the exact heat capacity depends partly upon the composition of the commercial product.

2. The heat capacity of both of these substances tends to vary considerably with temperature. For example, the heat capacity of cooking oil might be .54 cal/g-deg at 20 °C and .65 cal/g-deg at 70 °C. Therefore, the students actually measure the average heat capacity between two temperatures.

ANSWERS TO DISCUSSION QUESTIONS:

1. The stopper reduces the amount of heat lost to the atmosphere through evaporation.

2. Aside from routine errors in weighing, there are several other sources of error. Some ice is melted by heat from the atmosphere and from the glass. The glass also absorbs heat from the liquid which tends to make the final temperature of the liquid lower than it should be. In addition, the amount of liquid may be slightly less than 80 g, since some liquid adheres to the walls of the beaker used for weighing. Also, some of the ice might start out at a temperature lower than 0 °C.

3. As explained in Sections 10-2 and 10-3, hydrogen-bonding substances have relatively high heat capacities. If hydrogen bonding is considered to be an important factor contributing to the heat capacity of a molecule, the oil and the ethylene glycol would be expected to have little hydrogen bonding.

LESSON 11: AN INTRODUCTION TO ORGANIC CHEMISTRY

RATIONALE:

Since most nutrients are organic compounds, a knowledge of some basics of organic chemistry is a prerequisite to an understanding of nutrition. Similarly, most of the chemicals found in living organisms are organic compounds. In Lesson 11, the structures of hydrocarbons and alcohols are considered and the nomenclature of organic chemistry is introduced.

OBJECTIVES:

The student will:

- define alcohol, functional group, hydrocarbon, isomer, saturated, unsaturated.
- identify alcohols and hydrocarbons when shown a variety of structural formulas.

- explain in what way a structural formula is more descriptive than a molecular formula.
- construct a three-dimensional model of a molecule when provided with the structural formula.
- write the structural formulas for all isomers of butane and pentane.

SEQUENCE: ST-11; Activity 11

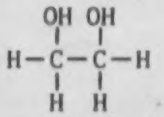
SUGGESTIONS:

1. You may wish to begin a discussion of ST-11 and then have the students work on Activity 11 before completing ST-11. The activity should make the material on molecular structure more understandable.

2. ST-11 was written to include both hydrocarbons and alcohols so that the students would be exposed to the system of nomenclature used in organic chemistry. It may be that more than one period will be required to teach this material.

3. The planar structure on the following page can be copied and used by students or by you to demonstrate the nature of a tetrahedron. Cut along the solid lines and fold along the dotted lines so that the four sides shown by hatched lines are on the outside. The structure that results is a tetrahedron and needs no tape or glue to be held in place.

4. You may wish to point out that ethylene glycol, which was used in Laboratory Activity 10, is an alcohol. Its structural formula is

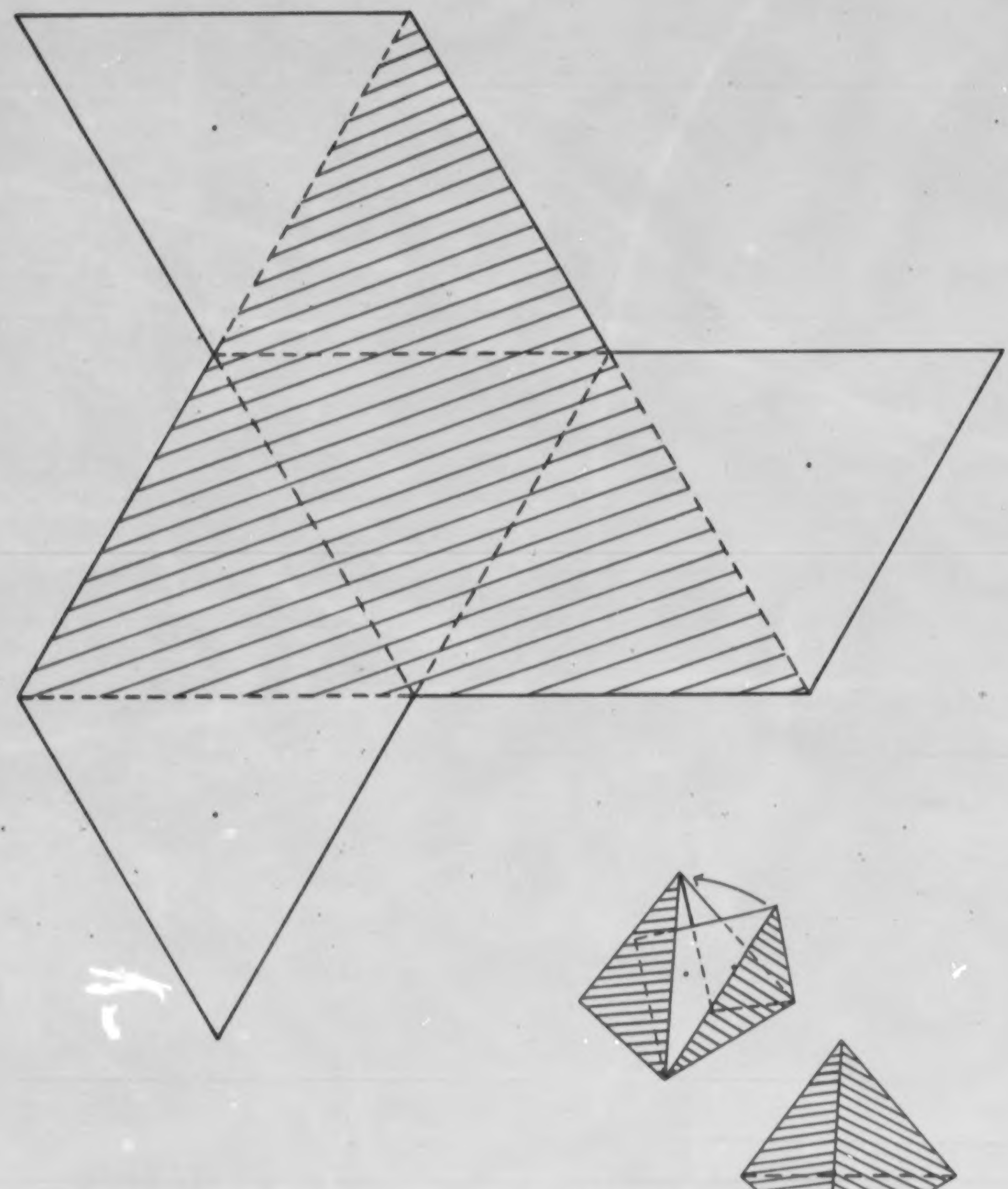


$$\begin{array}{ccccccc} & & OH & & OH & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Students may wish to make a model of this compound. Molecular models can be used to review nomenclature. Models of methane and methyl alcohol, and of ethane and ethyl alcohol can be compared.

5. Models can be used by students in responding to Problem Set 11, especially Question 3. (If a sulfur atom is called for, use an oxygen ball.) If desired, models can be used in conjunction with later Problem Sets as well.

6. You may wish to remind the students that models of various sorts are used in all three biomedical courses. Check with the other instructors to learn what models they are currently using, and use this information to hold a discussion comparing the nature and functions of the different kinds of models.



KEY--PROBLEM SET 11:

1. a. inorganic; b. organic; c. organic; d. organic
2. a. hydrocarbon; b. neither; c. alcohol; d. neither
3. a. isomer; b. equivalent; c. equivalent; d. equivalent
4. 1d. and 2c.

INFORMATION ON ACTIVITY 11:

TEACHING NOTES:

1. The purpose of this activity is to reinforce the basic organic chemistry introduced in ST-11. By use of three-dimensional models, the students will obtain a more accurate view of molecular structures than they can get from two-dimensional structural formulas.

2. Anticipated time: one to two periods.

3. You may want to mention that while model building may look like playing with toys, it is not "kids' stuff." For example, model building was instrumental in determining the structure of DNA.

4. The format is a programmed text to allow the students to find answers by themselves at their own rate. It may be necessary to explain the use of a programmed text. In particular, one point should be stressed--a programmed text can work well only if the reader answers the questions as directed without peeking at the answers. If a student "cheats," he may be deluding himself about his mastery of the material.

5. The molecular models to be used here are the same as were recommended in Unit I (Carolina Biological #56-2150). These models are fairly expensive, but may be used over and over again in this and in other courses. In addition, supplementary uses of these models are suggested in many places throughout the remainder of the course.

If a number of models are needed, check several catalogs for price. Some supply houses such as Sargent-Welch and Wards offer a quantity discount. In Wards 1974-1975 catalog, single model kits (82W1001) cost $6.95 and 12 kits can be obtained for $69.00.

It is also possible to buy individual balls and pegs in large quantities, and this may be the least expensive way to stock up for this activity. Other kits may be used, but will require slight modifications of the programmed directions. For example, hydrogen atoms may be a different color.

As an alternative, molecular models may be made from stained styrofoam balls and toothpicks. Detailed instructions for preparation of balls and sticks for models are given in "Guidebook to Constructing Inexpensive Science Teaching Equipment. Vol. II: Chemistry," 1972. This source may be obtained (at a slight cost) by writing to:

Inexpensive Science Teaching
Equipment Project
Science Teaching Center
University of Maryland
College Park, Maryland 20740

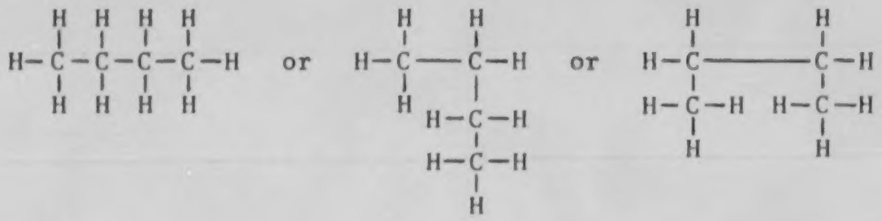
6. Some pegs may be difficult to insert into the balls. It may be helpful to have available some fine-grade sandpaper to sand the pegs slightly as needed.

7. It is desirable to have the students work in groups no larger than three. If insufficient kits are available, some students could begin studying LA-12 while others work with models.

8. You may want to stress the fact that in organic compounds, all the holes in the models should be filled. The one exception in the kit described is the nitrogen ball which has five holes, but forms only three covalent bonds in the structures with which we will be concerned. (In our kit, the two holes that are not to be used are painted.)

9. Questions 9 and 10 deal with water and hydrogen bonding. You may want to mention that the kits do not show the true bond angle for water. The angle obtained with the kit is 90°; the correct angle is 104.6°.

10. Students may need some convincing that compounds may look different in structural formulas, but are actually the same compound. For example, butane may be shown as



If this seems to be a problem, they can be referred to Section 11-2.

11. The springs may be damaged if students do not insert and remove them with a clockwise twist (Question 20 of the activity). This may merit emphasis.

12. In Question 23, another possible answer is that ethylene cannot rotate as freely as ethane. This is because of the double bond in ethylene. Most students are unlikely to detect this subtle difference, so we left it out of the answer. It is not crucial to their mastery of the concepts.

13. Because of the programmed format, students will vary in the time it takes them to perform this activity. It can be lengthened by suggesting other models to make, or shortened by eliminating questions.

MATERIALS: (per 10 set-ups)

10 molecular model kits (see Teaching Note 5)
The components of a kit are given in Activity 11.

LESSON 12: (A) CARBOHYDRATE CHEMISTRY
(B) NUTRIENT ANALYSIS

RATIONALE:

Since carbohydrates are a major class of nutrients, ST-12 considers their chemical structure. The differences between monosaccharides, disaccharides and polysaccharides are emphasized as well as the differences between monosaccharide isomers. ST-12 also describes the process of hydrolysis, which occurs during digestion of carbohydrates. In LA-12 the students begin an analysis of the nutrient content of several foods.

OBJECTIVES:

The student will:

- explain how a monosaccharide, disaccharide and polysaccharide differ.
- write the reaction for hydrolysis of a disaccharide, showing the structural formulas of the products, when given the formulas for the reactants.
- explain that hydrolysis is important in digestion because it is the process by which fats, proteins and carbohydrates are broken down into smaller molecules.

- outline a method for the quantitative analysis of fats, proteins and water in a food.

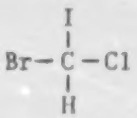
SEQUENCE: ST-12; LA-12

SUGGESTIONS:

1. Molecular models would be very useful as a teaching device in this lesson. The subtle differences between the isomers, glucose and galactose, can be readily demonstrated with ball-and-stick models. However, it is necessary to use springs instead of wooden pegs to construct the rings. Also, a comparison of glucose and galactose will require two kits. The kits may be used in different ways. For example, you could construct models prior to class for use in a class discussion or assign problems to individual students or ask for volunteers to prepare some complex organic structures.

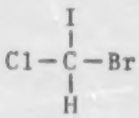
Molecular models can also be used to demonstrate the dehydration synthesis of a disaccharide from two monosaccharides and the reverse process, hydrolysis of a disaccharide.

2. Although optical isomers were not discussed in the Student Text, this could be done with suitable models. With simple models such as



$$\begin{array}{c} \mathrm{I} \\ | \\ \mathrm{Br-C-Cl} \\ | \\ \mathrm{H} \end{array}$$

(A)



$$\begin{array}{c} \mathrm{I} \\ | \\ \mathrm{Cl-C-Br} \\ | \\ \mathrm{H} \end{array}$$

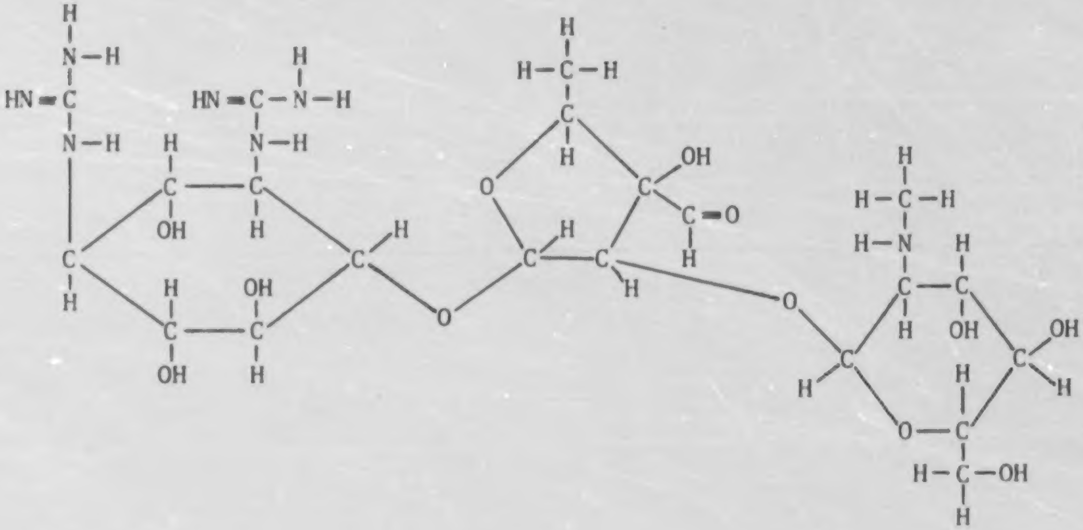
(B)

you can point out such things as the following. (a) Optical isomers are mirror images of each other. (b) A carbon compound with four different atoms or groups attached to one carbon (such as A and B in the figure) is said to be optically active. This means that it rotates plane-polarized light in a specific direction. (c) Structures A and B are optical isomers. (d) Optical isomers rotate plane-polarized light in opposite directions, and are designated D- or L-isomers depending upon which direction the light is rotated. (e) Aside from the fact that many chemists find optical isomers intrinsically interesting, this kind of isomerism is important to life. For example, proteins in the human body are composed exclusively of amino acids of one particular isomer, L-isomers. This phenomenon is crucial to the functioning of the proteins.

There is a great deal more that can be said about optical isomerism and life. You may wish to refer to a biochemistry textbook for a more thorough discussion.

3. The nutrient analysis activity is unlike any of the other activities that the students have performed, since it is designed to require several periods and is cumulative. Since much effort will be invested in this activity, it is especially desirable that the students understand the goals and know what they are doing and why. Some time at the beginning of LA-12 could be dedicated to an outline of the entire activity. The general outline on p. 44 of the Laboratory Manual would be a good starting point.

4. The students may be intersted to know that the antibiotic streptomycin is an unusual carbohydrate derivative. The structure is shown below. Some brave student(s) might attempt to make a molecular model of streptomycin.



KEY--PROBLEM SET 12:

1. a. Carbon, hydrogen; b. Carbon, hydrogen, oxygen

2. Saturated: b, c

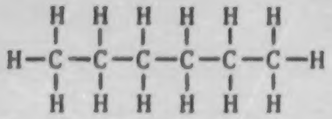
   Unsaturated: a, d

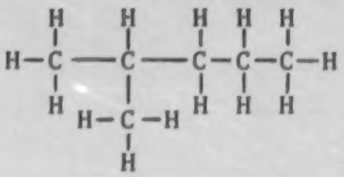
3. a. Hydroxyl

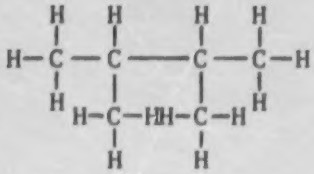
   b. —O—H

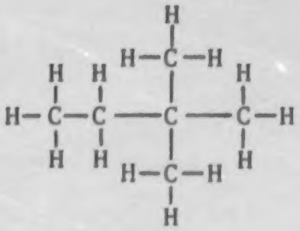
4. a, c, d

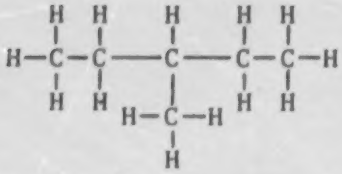
5 and 6.



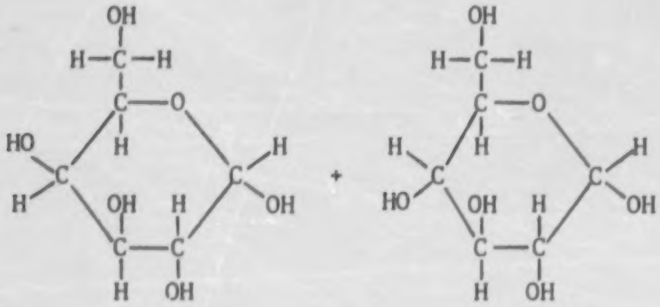








7.



INFORMATION ON LABORATORY ACTIVITY 12:

TEACHING NOTES:

1. The purpose of this activity is to familiarize the student with some of the procedures used in the nutrient analysis of a food.

2. Because the tests involved in the activity are quantitative, great attention must be paid to the accurate acquisition and recording of data. Therefore, the activity will also provide the students with an opportunity to improve on many of the laboratory techniques they have learned earlier.

3. The specific foods chosen for this analysis contain little carbohydrate. Carbohydrates interfere with the procedure used for the determination of protein content--they result in a suspension that cannot be filtered out after digestion with acid-pepsin. If you wish to let the students select other foods for analysis we suggest a few guidelines: (a) limit the choices to foods that contain no significant amount of carbohydrate, (b) these "trial" foods should only be used

as supplements, i.e., the student's first choice should originate from one of the foods we specify to assure reasonable results for at least one food tested, (c) the best choices for alternate foods would be meats, fish, poultry and hard cheese.

The foods that were analyzed in our laboratory were medium and regular grades of hamburger meat, all-beef hot dogs, butterfish (a white ocean fish) and Swiss cheese. (Medium-grade hamburger contains a lower percentage of fat than the regular grade.)

4. The procedure is written for certain parts to be performed by a team of two students. For example, when the biuret and the egg white standard solutions are prepared during Period I, it is assumed that both students will help prepare all those solutions. The solutions will then be shared in subsequent parts of the activity. For this reason the materials lists in the activity specify the quantities of equipment necessary for a team of two students. (This is true even for those parts in which the students are to work independently.) The following chart indicates which parts of the activity are team efforts and which may be performed by each student individually.

PERIOD I	Make biuret solution Make egg white acid-pepsin solutions	Teams
PERIOD II	Filter egg white solutions and store Make food acid-pepsin solutions	Teams Individuals
PERIOD III	Filter food solutions and store Dry food samples	Individuals
PERIOD IV	Weigh dried food samples Extract fat with Freon and redry food	Individuals
PERIOD V	Perform colorimetry on egg white standard solutions and construct calibration curve	Teams
PERIOD VI	Perform colorimetry on food solutions Calculate protein, water and fat percentages	Individuals

5. We suggest that lab partners choose different foods to discourage "dry-labbing." It would also be useful for several students in the class to test each kind of food so that at the end of the sequence students will be able to compare results with one another.

6. Reagents at the stock table should be divided into three or four containers to avoid unnecessary congestion.

7. Since this will be the most complex activity the students have performed, you may wish to emphasize the importance of accurate labeling of solutions and food samples, as well as careful recording of data.

8. The materials list was compiled with the assumption that each student will analyze two foods. If you lack sufficient glassware you might consider limiting the analysis to one food per student.

9. Although the procedure is written in terms of six lab periods, a total of eight lessons have been set aside for it in the teaching sequence of the unit. This was done to allow extra time for completion of the activity and for a discussion of the results.

10. If you wish to shorten the activity, you might provide the students with the calibration curve for protein concentrations. This will significantly reduce the total time required for the activity. Having each student analyze only one food may reduce the time by 10 to 15 minutes in each period.

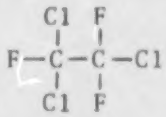
11. The activity can be expanded by having students perform an analysis of more than two foods. However, this will require more equipment and supplies.

12. The six periods need not be on consecutive days, but once the egg white standard solution or the food acid-pepsin solutions have been placed in the incubator, they must be removed, filtered and stored the next day. If the activity is performed in the sequence shown in TN #4, Periods I, II and III must occur on three consecutive days (i.e., Period I may be scheduled for a Monday, Tuesday or Wednesday).

13. If you wish to reduce the cost of the activity, this can be done by having the students choose only one food.

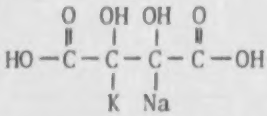
14. Students should be cautioned to handle the reagents with care. Pipetting should be accomplished with a bulb or syringe pipet.

15. Since at the time this activity is being performed organic chemistry is being developed in the text, you might want to show the students the structural formulas for some of the chemicals used in the lab such as Freon (trichloro-trifluoroethane) and $KNaC_4H_4O_6$ (potassium sodium tartrate).



$$\mathrm{F-\overset{\overset{Cl}{|}}{\underset{\underset{Cl}{|}}{C}}-\overset{\overset{F}{|}}{\underset{\underset{F}{|}}{C}}-Cl}$$

trichloro-trifluoroethane



$$\mathrm{HO-\overset{\overset{O}{\|}}{C}-\overset{\overset{OH}{|}}{\underset{\underset{K}{|}}{C}}-\overset{\overset{OH}{|}}{\underset{\underset{Na}{|}}{C}}-\overset{\overset{O}{\|}}{C}-OH}$$

potassium sodium tartrate
(discuss following ST-15)

16. For your convenience, the remainder of these teaching notes are divided according to the appropriate period.

PERIOD I:

1. In making the biuret solution, it is important that the various chemicals be added in the order specified. The copper sulfate will not dissolve in a basic solution, making it imperative that the NaOH be added after the copper sulfate is dissolved in water with the potassium sodium tartrate.

2. The two students who cooperate in making up the biuret reagent should use only their own batch for all the subsequent tests they run. This is necessary in order to obtain consistent results in the colorimetric analysis.

3. In making up the egg white standard solutions, each student of the team should share the preparatory work to provide the team with a total of five solutions of known protein concentration.

4. To make up the egg white standard solutions the yolks and white of the eggs must be separated. You may wish to demonstrate the technique: pouring the yolk back and forth between the two halves of the broken egg shell. Students should also receive instructions on how to discard the remaining yolks, if you have no use planned for them. Diluting the yolks with water and pouring them down the drain is one acceptable method.

5. An alternate way to make up the egg white solutions would be to have each team make up 150 ml of a solution containing 1.50 g of protein (i.e., 13.6 ml of egg white) per 50 ml of solution. This solution could be incubated and portions of the filtrate diluted to obtain the standard solutions. (See table for dilution instructions.)

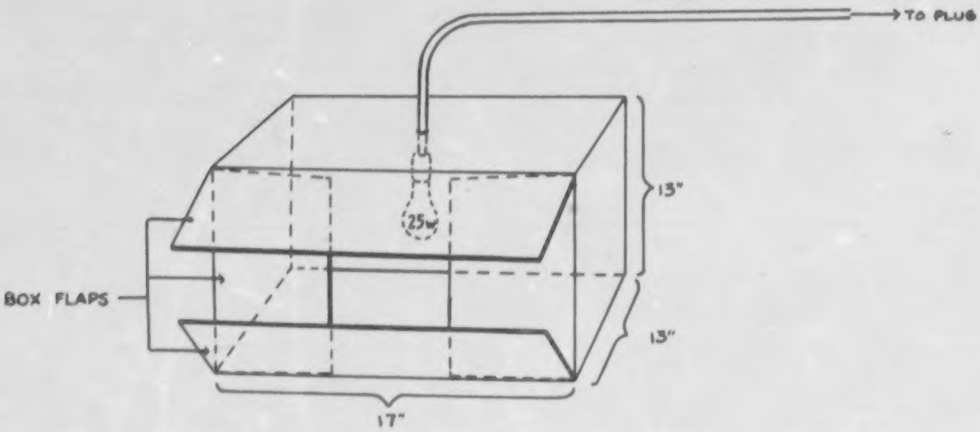
STANDARD EGG WHITE SOLUTION

g of protein/50 ml	ml original solution	ml water
0.25	8.3	41.7
0.50	16.7	33.3
0.75	25	25
1.00	33.3	16.7
1.50	50	----

6. A total of 75, 125-ml Erlenmeyer flasks are called for in this part of the activity. If you do not have sufficient flasks, 150-ml beakers may be used

instead. However, if this is done care should be taken to seal the beakers with Parafilm before the egg white solutions are incubated.

7. The procedure calls for the egg white standard solutions to be incubated for 24 hours. If you don't have a commercial incubator with sufficient space, you can made a suitable substitute. An easy way to do this is to set up a number of cardboard cartons with 25-watt light bulbs as heat sources. The boxes should have dimensions of about 13 x 13 x 17 inches. (See figure below.) Each one of these incubators will hold about 16 of the 125-ml flasks, so that you will probably need to make three or four of them depending on your class size. Be sure that the bulb doesn't touch the box, because of the potential fire hazard.



INCUBATOR

8. The function of the acid-pepsin solution is to dissolve the protein. Large food proteins tend not only to be insoluble in themselves, but also they form insoluble complexes with fats and lipid membranes. The acid-pepsin functions both to break off pieces of proteins, thus forming more soluble polypeptides, and to free proteins bound to fats and other lipids. The mechanical grinding and homogenizing process in this activity is even more effective in freeing bound proteins.

PERIOD II:

1. All meats and fish will need to be homogenized in a blender. To do this place chunks of the food in the blender and, starting with a slow speed, work up to the highest one. You will not need to add water or any other fluid. The blending time required is about one minute. When finished the meat should look

"whipped." It would be convenient to have one blender for each meat and fish. Perhaps one or two students could bring one from home for a day. If not, one blender will suffice.

2. The amount of each food necessary will depend on how many students choose a given food. Each student will need 10 g of the foods he chooses (for the entire activity).

PERIOD III:

1. Foods that we have listed should be easy to filter. If problems arise in filtration there are two alternate techniques that may help.

a. If you have the facilities, vacuum filtration with a trap may be used.

b. You may centrifuge a suspension first to separate the particulate matter from the solution. This will make filtration easier in a later step. After centrifugation there will be solid matter at the bottom of the tube, followed by a layer of solution, topped by a layer of fat. Most of the fat layer can be removed with a scoopula. The remaining solution can then be decanted through the funnel without disturbing the solid at the bottom of the tube.

2. When preparing the samples for drying, it is not necessary to start with "blender-treated" meats and fish. Chopping the sample into very small pieces is sufficient.

3. We have specified evaporating dishes for drying the food samples rather than flasks for the following reasons.

a. Since flasks are required throughout the activity, it is likely that there will not be enough flasks available for use in the drying step.

b. It is desirable to use a container into which the filter paper with the food sample can be placed for drying during Period IV. This is important because some of the food may remain in the initial container. The containers, filter paper and filtered food should all be dried again and reweighed together.

If you do not have sufficient evaporating dishes, 150-ml beakers should serve just as well.

4. When labeling the evaporating dishes, or beakers, that are to be placed in the oven, stick-on labels should be used because the wax from a glass-marking pencil might melt and run in the oven. Labels should be added to the containers before they are weighed.

5. The temperature at which the food should be dried is 70 to 80 °C (approximately 155 to 180 °F). Temperatures in excess of 200 °C will char the food.

6. We found that 24 hours was sufficient drying time. Drying for 48 hours resulted in no appreciable change in the dry weight of the sample.

PERIOD IV:

1. When the cheese is heated during the drying process it tends to form a hard layer in the bottom of the evaporating dish. It may be necessary to transfer this crusty layer of cheese to a mortar and grind it up with the pestle before adding Freon. After the cheese is ground up, the Freon is added and the mixture is then returned to the evaporating dish. If this method is used the mortar should be rinsed at least two or three times with small amounts of Freon to minimize loss of food.

2. If your laboratory is equipped with good hoods, chloroform may be substituted for Freon. Chloroform is much less expensive.

PERIOD V:

1. You may wish to go over the principles involved in the construction of a calibration line for the colorimeter to make sure the students understand what they are doing.

2. Only one team should use a BIP at a time. When that team has recorded the data for all their egg white standard solutions, then another team may proceed. This is necessary since the BIP is standardized with one team's blank, and this standardization is valid only for their readings.

3. Each team should record the numbers of the BIP and test well that they use in this portion of the activity so that they can use the same ones in Period VI.

4. In order to avoid congestion at the BIP's, you might have half the class perform the colorimetry on their egg white standard solutions during Period IV while the remaining students do the fat-extraction step. The next day roles can be exchanged. (The food samples may be left in the oven for another 24 hours without any appreciable change in the dry weights.)

5. The solutions to be tested should be allowed to sit for at least 15 minutes after the biuret reagent is added. There should be no further development of color from the biuret reaction after this time.

PERIOD VI:

1. The procedure for Period VI is essentially the same as that of Period V, except that this time the students will analyze food solutions for concentrations of protein. Again, it is desirable to avoid congestion at the BIP's. Some teams might use the BIP's while others perform the calculations to determine the water and fat contents of their food samples. Or if they did not finish constructing the calibration line during Period V, they might use this time to do it.

2. Students should be reminded to use the same BIP and test well for this part of the activity as they used for the analysis of the egg white standard solutions in Period V.

MATERIALS: (for 15 set-ups, Periods I through VI)

- 10 g copper sulfate ($CuSO_4 \cdot 5H_2O$)
- 30 g potassium sodium tartrate ($KNaC_4H_4O_6 \cdot 4H_2O$)
- 120 g sodium hydroxide (NaOH)
- 30 g potassium iodide (KI)
- 80 g sodium chloride (NaCl)
- 32 g potassium chloride (KCl)
- 40 g pepsin
- 3 liters Freon TF
- 83 ml hydrochloric acid (HCl), conc.
- 1 liter sand
- 3 dozen eggs, large
- foods to be analyzed (see TN #2, Period II)
- blender(s)
- 2 to 3 cheese graters
- 3 to 4 incubators (see TN #7, Period I)
- oven
- 15 beakers, 250-ml
- 30 beakers, 150-ml
- 15 beakers, 600-ml
- 75 Erlenmeyer flasks, 125-ml (see TN #6, Period I)
- 15 Erlenmeyer flasks, 250-ml
- 15 graduated cylinders, 100-ml
- 15 graduated cylinders, 10-ml
- 15 pipets, 1-ml
- 15 pipets, 10-ml
- 105 cuvets, 16 x 125 mm, Pyrex
- 135 test tubes, 10-ml capacity or greater
- 30 funnels, 2 oz, short-stemmed
- 60 evaporating dishes (or 150-ml beakers)
- 10 mortars and pestles
- 75 rubber stoppers, #5 (or cork, #12) (optional)
- 30 stirring rods, glass
- 15 scoopulas
- 15 knives
- 15 teaspoons
- 15 glass-marking pencils
- 15 balances
- 15 test-tube racks
- filter paper, Whatman No. 1, 11-cm
- labels
- 10 BIP colorimeters
- Parafilm
- paper tissues
- assorted containers for chemicals and solutions at stock table
- large container for mixing 8 liters of acid-pepsin solution

A breakdown of the Materials List by period is given below.

Period I:

10 g copper sulfate ($CuSO_4 \cdot 5H_2O$)
30 g potassium sodium tartrate ($KNaC_4H_4O_6 \cdot 4H_2O$)
sodium hydroxide solution
30 g potassium iodide (KI)
acid-pepsin solution
3 dozen eggs, large
30 beakers, 150-ml
15 beakers, 600-ml
15 Erlenmeyer flasks, 250-ml
75 Erlenmeyer flasks, 125-ml (see TN #6, Period I)

75 rubber stoppers, #5 (or cork, #12) (optional)
15 scoopulas
15 stirring rods
15 graduated cylinders, 100-ml
15 graduated cylinders, 10-ml
15 glass-marking pencils
15 balances
3 to 4 incubators (see TN #7, Period I)
Parafilm

Period II:

acid-pepsin solution
food samples (TN #2, Period II)
1 liter sand
3 to 4 incubators
2 to 3 cheese graters
60 Erlenmeyer flasks, 125-ml
60 rubber stoppers, #5 (or cork #12) (optional)
10 mortars and pestles
15 beakers, 250-ml
75 test tubes, 10-ml capacity or greater

15 graduated cylinders, 100-ml
15 graduated cylinders, 10-ml
30 funnels, 2 oz, short-stemmed
15 glass stirring rods
15 glass-marking pencils
15 test-tube racks
15 balances
15 teaspoons
filter paper, Whatman No. 1, 11-cm
blender
Parafilm

Period III:

food samples
2 to 3 cheese graters
15 knives
15 graduated cylinders, 10-ml
60 evaporating dishes (or 150-ml beakers)
60 test tubes, 10-ml capacity or greater
15 test-tube racks

30 funnels, 2 oz, short-stemmed
15 balances
15 glass-marking pencils
filter paper, Whatman No. 1, 11-cm
labels
oven
Parafilm

Period IV:

3 liters Freon TF
30 beakers, 150-ml
15 beakers, 600-ml
15 graduated cylinders, 100-ml
30 glass stirring rods
15 glass-marking pencils
30 funnels, 2 oz, short-stemmed
15 balances
filter paper, Whatman No. 1, 11-cm

Period V:

acid-pepsin solution
biuret solutions
egg white standard solutions
105 cuvets, 16 x 125 mm, Pyrex
15 pipets, 1-ml
15 pipets, 10-ml
15 glass-marking pencils
10 BIP colorimeters
paper tissues

Period VI:

acid-pepsin solution
biuret solutions
filtered food sample solutions
90 cuvets, 16 x 125 mm, Pyrex
15 pipets, 1-ml
15 pipets, 10-ml
15 glass-marking pencils
10 BIP colorimeters
paper tissues

PREPARATION OF REAGENTS:

NaOH solution: Dissolve 120.0 ± 0.5 g of NaOH in 2 liters water.

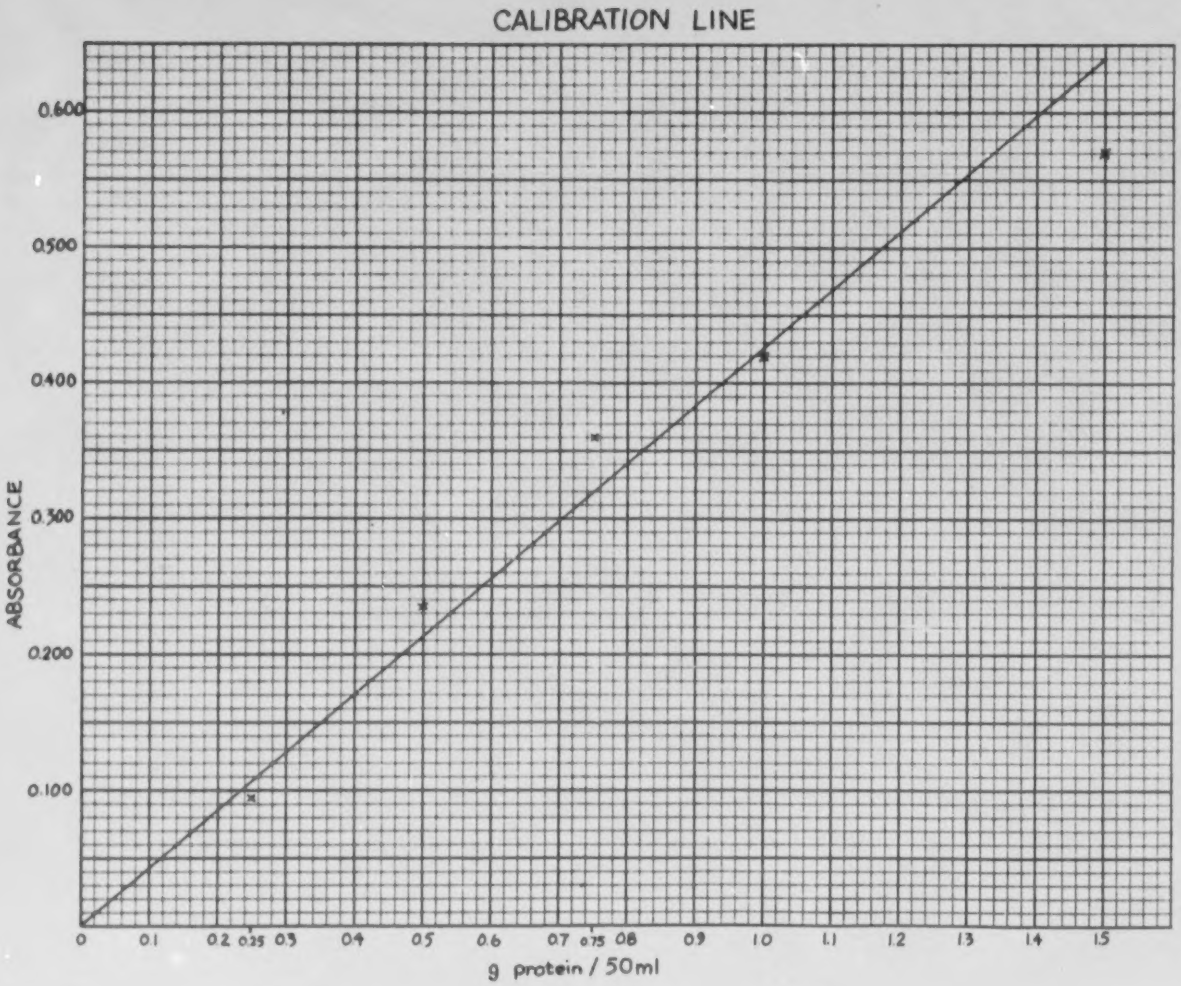
1 M HCl: Add 83 ± 1 ml conc. HCl to 800 ml water. Dilute to 1 liter.

Acid-pepsin solution: Dissolve 80 ± 0.1 g NaCl, 32 ± 0.1 g KCl and 40 ± 0.1 g pepsin in 7200 ml water. Add 800 ml of 1 M HCl. Store in refrigerator. Will keep for 3 weeks.

ANTICIPATED RESULTS:

1. Egg white standard solutions: The following values for % T and absorbance were obtained and used to construct the calibration line shown on the next page.

g protein/50 ml	% T	absorbance
0.25	80.0	.095
0.50	58.0	.235
0.75	43.5	.360
1.00	38.0	.420
1.50	27.0	.570



2. % protein in food samples: The following values were obtained for % T, absorbance and g protein/50 ml. The % protein in the food samples, as calculated from these values, is also shown.

food	% T	absorbance	g protein/50 ml	% protein
regular grade hamburger	47.0	.330	0.78	15.6
medium grade hamburger	46.5	.330	0.78	15.6
all beef hot dog	60.0	.220	0.52	10.4
butterfish	65.0	.185	0.44	8.8
Swiss cheese	41.0	.390	0.92	18.4

3. % water in food sample: The following values were obtained.

food	% water in sample
regular hamburger	56.0
medium hamburger	64.6
all beef hot dog	53.0
butterfish	81.0
Swiss cheese	38.2

4. % fat in food sample: The following values were obtained.

food	% fat in sample
regular hamburger	23.8
medium hamburger	12.2
all beef hot dog	27.8
butterfish	6.0
Swiss cheese	24.0

ANSWERS TO DISCUSSION QUESTIONS:

1. The water, fat and protein content of the foods analyzed, as determined by referring to tables of nutrient values, is as listed below.

food	% water	% fat	% protein
regular hamburger	54.0	20.0	24.7
medium hamburger	57.3	17.0	25.6
all beef hot dog	57.0	26.7	12.5
butterfish	80.0-90.0	2.0-7.0	16.2
Swiss cheese	39.0	28.5	28.5

For all the foods we tested the water and fat content values compared favorably with those listed in the table above. The protein values were low by as much as 10.1. For example, the theoretical value for protein in regular grade hamburger is 24.7% and the colorimetric analysis gave a value of 15.6%. The most probable cause of this rather large error is the failure to get all of the proteins into solution. It is very difficult to release all the proteins from the cell membranes and other macromolecules they are attached to. Presumably if equipment were available that would produce an even finer homogenate, the results would be closer to those given in food tables.

2. One could presumably determine the % protein in the food sample by assuming that what is left of the food, after drying it and extracting the fat, is almost totally protein. If the necessary calculations are made, the following values result.

Food	% Protein
regular hamburger	20.2
medium hamburger	23.2
all beef hot dog	19.2
butterfish	13.0
Swiss cheese	37.8

The values calculated in this manner are much closer to the values given in the nutrient tables, except in the cases of hot dogs and Swiss cheese. The exceptions may be explained by the fact that these two foods contain a small percentage of carbohydrate, which has been incorporated into the figure for protein content because of the manner in which the calculations were performed.

3. The method is not applicable for foods containing carbohydrates because the value calculated for protein will be too high because of the presence of carbohydrate. This could be compensated for by first calculating the value for carbohydrate and protein content and then subtracting the carbohydrate content from this. The value for the carbohydrate content would have to be obtained from a table on nutrient values of foods.

4. One can determine whether the 24-hour drying period is sufficient to remove all the water by drying the food sample for a much longer period of time, say 72 hours, and weighing the sample periodically. If the masses are the same after 24 hours, 48 hours and 72 hours, then one may assume that all the water was removed in the initial 24-hour period. When the activity was performed in our laboratory, this technique was used to determine that a drying period of 24 hours was sufficient.

5. Sources of error include the following:

   a. weighing error, volume measurement error,

   b. error due to loss of food sample in stirring and transfer procedures,

c. calculation error,

d. error in standardizing the colorimeter or reading the % T values,

e. error in construction of the calibration line,

f. error due to incomplete solubilization of protein in food sample,

g. error in mixing the biuret solution,

h. errors in recording data, etc.

LESSON 13: CARBOHYDRATES IN THE DIET

RATIONALE:

The chemistry of carbohydrates was the topic of ST-12. In ST-13 the physiological role of carbohydrates is considered. The desirability of consuming carbohydrates in the form of starch, as opposed to sugar, is discussed in relation to nutritional value, dental health and risk of atherosclerosis.

OBJECTIVES:

The student will:

- state that the main physiological function of carbohydrates in the human body is to provide energy.
- list an advantage of using carbohydrates rather than fats or proteins as an energy source.
- list at least two disadvantages of consuming carbohydrates in the form of sugar rather than starch.
- define atherosclerosis.
- explain what happens when the liver's capacity to store glycogen is exceeded.
- discuss the hypothesis that increased sugar consumption causes an increased risk of atherosclerosis.

SEQUENCE: ST-13; LA-12 (or reverse)

SUGGESTIONS:

1. This might be a good time to consider inviting a guest speaker on atherosclerosis and nutrition. A nutritionist or dietitian or physician with experience in this area might be a good choice.

2. Students may have parents or other relatives who have atherosclerosis and who are on special diets. Comments of the students on such diets may be of interest to the class.

LESSON 14: (A) HYPOGLYCEMIA
(B) HOMEOSTASIS

RATIONALE:

In ST-13 carbohydrates were discussed as the primary source of energy in the diet. Polysaccharides are broken down to monosaccharides in the digestive tract. Ultimately most of these monosaccharides are converted to glucose which can be oxidized to provide energy for the body. In this lesson, homeostasis, a central theme of physiology, is introduced via a discussion of hypoglycemia and blood-sugar level.

OBJECTIVES:

The student will:

- state two reasons why consuming large quantities of sugar just before an athletic event to provide "extra energy" is not a sound procedure.
- discuss the roles of insulin and glucagon in regulating the level of glucose in the blood.
- define hypoglycemia and list at least two possible causes of this condition.
- define and give at least one example of homeostasis.
- define negative and positive feedback and give one example of each.

SEQUENCE: ST-14; LA-12 (or reverse)

SUGGESTIONS:

1. After reviewing the case history on hypoglycemia, some of the students who are involved in competitive sports might contribute examples from personal experience about what they eat (or what the coach tells them to eat) prior to an athletic event. Such examples could then be evaluated using USDA Home and Garden Bulletin #72 and the material presented in ST-14 as guidelines. A guest speaker on the subject of nutrition for athletes is also a possibility.

2. The subject of homeostasis is one that will come up frequently in this curriculum. You may wish to elaborate on this concept and to provide additional examples, preferably those related to nutrition or to respiration. You may refer to any recent physiology text for examples.

One popular textbook example of homeostasis is body temperature control. The following three paragraphs illustrate how this example could be presented to a class and are written on a student level.

A thermostat is a wonderful device. You set it for 68 °F. On a cold day, the thermostat sends a signal to the furnace. The furnace goes on and produces heat. The house or apartment warms up; but when the temperature around the thermostat rises above 68 °F, the thermostat temporarily turns off the furnace until the room cools below the set temperature. The furnace continues to go on and off in response to signals from the thermostat.

We have a sort of thermostat within us. On a sweltering day or on a frigid winter day, our body temperature remains very close to 37 °C, so our "internal thermostat" must be very effective. How does our temperature regulation work? Generally, we maintain a body temperature above that of our environment, so our internal thermostat triggers more heating than cooling. In large part, we produce body heat as a by-product of chemical reactions in the liver. In very cold weather, besides insulating our bodies with lots of clothes, we sometimes shiver. This intensive muscular activity stimulates increased body reactions and, therefore, more heat generation.

Although our temperature regulation system lacks a built-in air conditioner, it does include a cooling device which involves sweating. The body sweats continuously; but as you know, when you get overheated during exercise or on a hot day, you sweat more. What happens is that the blood becomes a little warmer. This triggers the brain to signal the sweat glands in the skin to release more sweat. As the sweat evaporates, the body is cooled.

3. The mechanisms involved in regulation of blood-glucose level are complex and go well beyond those discussed in ST-14. You may find the background information on blood-glucose regulation useful as a brief review or as a resource for expansion of the lesson.

BACKGROUND INFORMATION ON REGULATION OF BLOOD GLUCOSE LEVEL:

The normal blood-sugar level is 80 to 100 mg per 100 ml of blood. When the blood-sugar level exceeds the normal range, homeostatic mechanisms are triggered that lower the level. These mechanisms include the following.

1. Glucose is transfered to liver and muscle cells where it is stored as glycogen.

2. Glucose is removed from tissues via glycolysis or fat synthesis, making it possible for more glucose to enter the tissues from the blood.

3. Glucosuria (excretion of glucose in the urine) occurs when the blood-glucose level reaches excessively high values (greater than 160 to 180 mg per 100 ml of blood).

There are actually more hormones involved in regulation of blood-sugar level than are mentioned in ST-14. Six hormones play a major role in homeostatic control of blood-sugar level. Only one of these hormones, insulin, is hypoglycemic (removes glucose from the blood). The others (growth hormone, adrenal cortical hormone, epinephrine, glucagon and thyroxin) all have hyperglycemic effects.

LESSON 15: CHEMISTRY OF ACIDS AND FATS

RATIONALE:

The chemistry of organic acids is considered in ST-15. Organic acids are especially relevant to nutrition because they are a constituent of fats, amino acids and other nutrients. An introduction to the chemistry of organic acids is followed by a discussion of the chemistry of fats and fatty acids. The chemistry of amino acids will be treated in ST-17.

OBJECTIVES:

The student will:

- write the structural formula of the carboxyl group.
- write an equation for the dissociation of an organic acid when given the structural formula of the acid.
- define an ester.
- write an equation for the dehydration synthesis of an ester from an alcohol and an acid, when given the structural formula of the ester.
- identify saturated, monounsaturated and polyunsaturated fatty acids when presented with a variety of structural formulas.
- write the equation for the hydrolysis of a fat, given the structural formula of the fat.

SEQUENCE: ST-15; LA-12 (or reverse)

SUGGESTIONS:

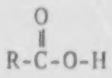
1. Molecular models of carboxylic acids can be made. You may wish to use a model to demonstrate how an organic acid dissociates. Models may be used to demonstrate both the dehydration synthesis of an ester from an acid and an alcohol, and the hydrolysis of an ester. It would be a good project for a group of ambitious students to construct a model of a triglyceride with long-chain fatty acids. To make a model of triolein, for example, students would need approximately six kits. Models may also be used with Problem Set 15.

2. To demonstrate the abundance of organic acids in foods, students could make a list of such compounds on food labels. Many acids listed on labels are organic acids. These compounds often end with the suffix "ate," which means the salt of an acid (e.g., calcium propionate). If this option is used, it will be necessary for students to check reference books to determine whether compounds suspected of being organic acids are indeed organic acids. Any college organic chemistry textbook or even a good dictionary is likely to be useful for this purpose.

3. You may find it useful in discussing ST-15 and ST-16 to remind students about those operations in LA-12 that involve fats. The nutrient analysis activities can add something to a discussion of the Student Text. Conversely, the treatment of organic chemistry in the Student Text should help to make the procedure of LA-12 more understandable.

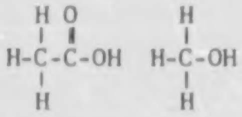
KEY--PROBLEM SET 15:

1. b,d

2. 

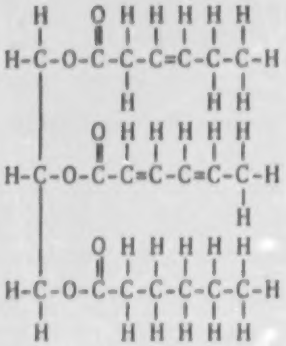
$R-\overset{\overset{O}{\|}}{C}-O-H$

3. alcohols: a,c,e
   organic acids: b,d

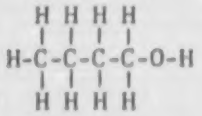
4. 

$H-\underset{H}{\overset{H}{C}}-\overset{\overset{O}{\|}}{C}-OH \quad H-\underset{H}{\overset{H}{C}}-OH$

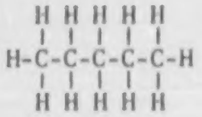
5. a. monounsaturated
   b. polyunsaturated
   c. saturated



$$\begin{array}{l}\mathrm{H_2C{-}O{-}CO{-}CH_2{-}CH{=}CH{-}CH_2{-}CH_3}\\ \mathrm{HC{-}O{-}CO{-}CH{=}CH{-}CH{=}CH{-}CH_3}\\ \mathrm{H_2C{-}O{-}CO{-}CH_2{-}CH_2{-}CH_2{-}CH_2{-}CH_3}\end{array}$$

6. a. 

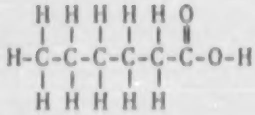
$\mathrm{CH_3{-}CH_2{-}CH_2{-}CH_2{-}O{-}H}$

b. 

$\mathrm{CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_3}$

c. normal-pentanoic acid

d. normal-hexyl alcohol

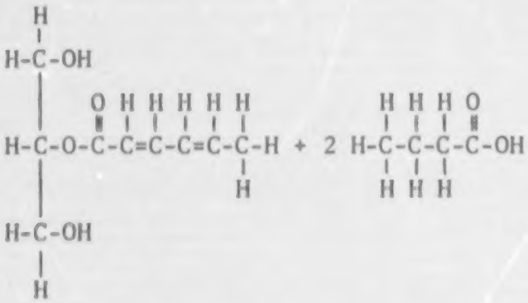
e. 

$\mathrm{CH_3{-}CH_2{-}CH_2{-}CH_2{-}CH_2{-}CO{-}O{-}H}$

7. a. ester
   b. acid
   c. hydrocarbon
   d. alcohol
   e. ester
   f. alcohol
   g. hydrocarbon

8. esters (monoglycerides) and fatty acids

9. a and d
   saturated: a,c
   monounsaturated: b,d
   polyunsaturated: e

10. 

$$\begin{array}{l}\mathrm{H_2C{-}OH}\\ \mathrm{HC{-}O{-}CO{-}CH{=}CH{-}CH{=}CH{-}CH_3} + 2\ \mathrm{CH_3{-}CH_2{-}CH_2{-}CO{-}OH}\\ \mathrm{H_2C{-}OH}\end{array}$$

LESSON 16: FATS IN THE DIET

RATIONALE:

The chemistry of fats was considered in ST-15. ST-16 treats the nutritional values of fats. The relationship of saturated fatty acids to atherosclerosis and heart attacks is also considered.

OBJECTIVES:

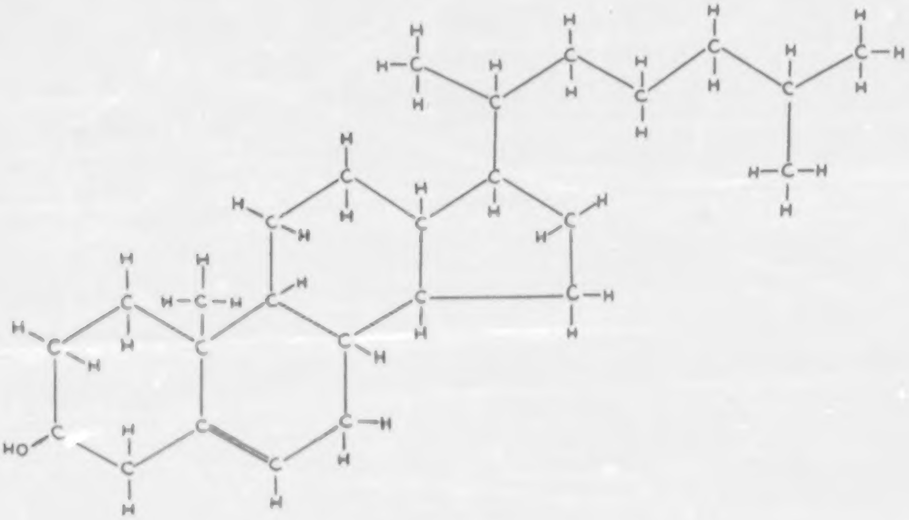
The student will:

- explain why polyunsaturated fatty acids are considered more desirable in the diet than monounsaturated and saturated fatty acids.
- list at least two ways to reduce the level of saturated fatty acids in a diet.
- define essential fatty acid.

SEQUENCE: ST-16; LA-12 (or reverse)

SUGGESTIONS:

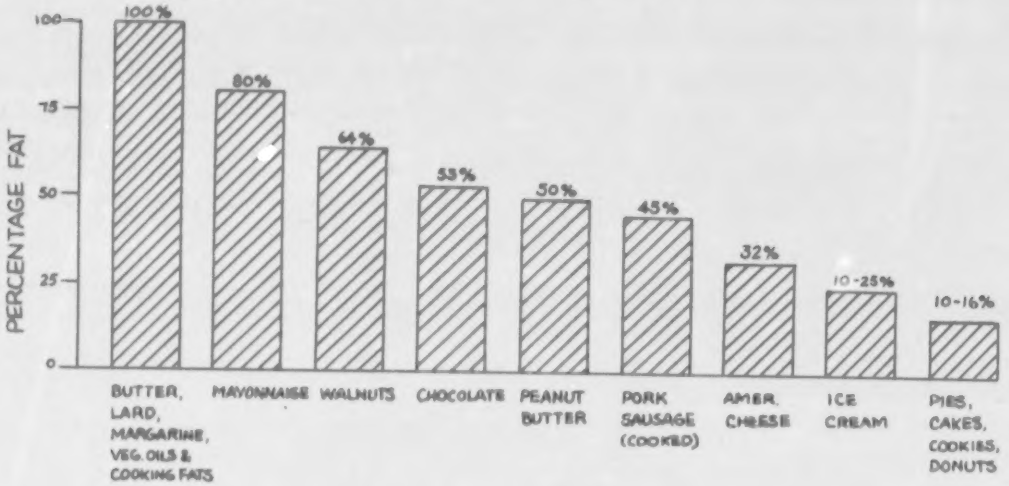
1. Students might be curious about the structure of cholesterol. It belongs to an important class of compounds known as steroids, which includes sex hormones, cortisone and vitamin D, as well as cholesterol. The structure is given below. One or more students could make a model of cholesterol using about three molecular model kits. From the structural formula or molecular model, you can point out that cholesterol is an alcohol (note OH group on left) and may be viewed as a hydrocarbon derivative.



2. Students might be interested in scanning the tables in USDA Home and Garden Bulletin #72 to investigate the relative proportions of saturated and polyunsaturated fatty acids in various foods. This would involve a comparison of the "saturated" column with the "linoleic" column.

3. You might wish to refer to milk as an example of the solubility properties of fats. Fats are insoluble in water. Thus, the fat in milk will rise to the top unless the milk is homogenized. Homogenization breaks up fat into fine particles which remain evenly distributed in the fluid. Fats in small droplets (as in homogenized milk) are more easily digested by lipases because the small droplets provide a greater area of exposure to the lipases.

4. The following bar graph shows the percentage of fats in some common foods. You may wish to post or reproduce this chart.



FAT-RICH FOODS

5. Students may be interested in learning about research aimed at producing milk and beef with more polyunsaturated fatty acids. This approach to improving the nutritional quality of beef and dairy products is sometimes referred to as "fooling the cow." The research is based on the observation that bacteria in the first of the cow's four stomachs reduce polyunsaturated fatty acids to saturated fatty acids. To avoid this conversion to saturated fatty acids, experiments are being done with grain that is coated to prevent it from being broken down in the first stomach. If the process works, the fatty acids that are unsaturated in the grain would still be unsaturated when they are absorbed into the cow's body.

LESSON 17: PROTEINS AND AMINO ACIDS

RATIONALE:

Proteins are one of the major classes of nutrients. They are digested to amino acids, which are absorbed and transported to cells. Cellular amino acids are used to build new proteins which then serve essential functions in the body as hormones, enzymes and antibodies and also contribute to the structure of skin, muscles, hair and bones. In ST-17, the structure and chemistry of proteins is considered in terms of their building blocks, the amino acids. The relation between three-dimensional structure and biological activity of proteins is also considered.

OBJECTIVES:

The student will:

- identify amines and amino acids when presented with a variety of structural formulas.
- define denaturation and explain how denaturation alters the biological activity of a protein.
- explain that the three-dimensional structure of a protein is necessary for its biological function.
- state that dehydration synthesis leads to the production of peptides from amino acids.
- state that hydrolysis leads to breakdown of proteins to amino acids.

SEQUENCE: ST-17; LA-12 (or reverse)

SUGGESTIONS:

1. Molecular model kits may be used to construct models of some of the amino acids. In addition, students can demonstrate formation of a peptide from amino acids by dehydration synthesis. Likewise, hydrolysis of a peptide can be simulated with models.

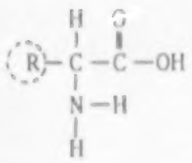
If several students or groups of students each make one amino acid, the amino acids can be joined together to make a polypeptide. With such a model, denaturation can be demonstrated by shifting an orderly structure such as a helix to a more random structure. A polypeptide model can show that various three-dimensional structures are possible by twisting the model into different shapes. This can be related to the fact that one particular shape is thought to correspond to the functional form of an enzyme (ST-4 and ST-17).

2. In Section 17-1, the fact that proteins of all forms of life are composed of approximately 20 different amino acids is stated and not elaborated on. There are many implications of this statement of possible interest to your students. A few relevant points are listed below for your consideration. More information may be obtained from a college biochemistry textbook.

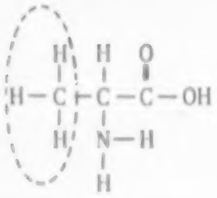
a. In spite of the vast difference in the appearance of different organisms, all living creatures have essentially the same amino acid components in their proteins. For example, bacteria and green plants have the same amino acids in their proteins as we do. This has evolutionary implications--one inference is that the amino acid composition of proteins has been conserved in evolution. (In turn, it is likely that the DNA code has changed little or not at all during the course of evolution. However, the DNA code will not be treated in the Student Text until a later unit.)

b. The similarity of amino acid composition is part of what the biologist, Van Neil, had in mind when he first wrote about the "unity of nature." The fact is that organisms are strikingly similar on the biochemical and cell physiological levels. It is this generalization that permits research involving mice and microorganisms to be applicable to human health. The unity of nature helps us to appreciate how insulin derived from a cow or pig may be useful in treatment of human diabetes.

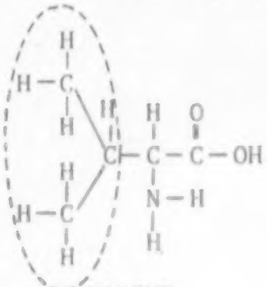
c. Both students and scientists are sometimes curious about the fact that there are only about 20 amino acids in proteins. For example, alanine and valine are found in proteins, but there is no evidence for amino acids in proteins having an ethyl R-group. The reasons why this is so is not known, but it is possible that the amino acids that are found in proteins reflect the amino acids present at the time of the origin of life on earth a few billion years ago. Research on this subject has revealed that some amino acids form more easily in simulated prebiological conditions. Refer, for example, to Fox and Dose, Molecular Evolution and the Origin of Life, W. H. Freeman Co., San Francisco, 1972.



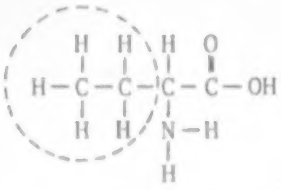
GENERAL FORMULA
AMINO ACID



ALANINE



VALINE

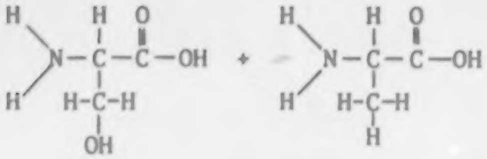


NOT FOUND IN
PROTEINS

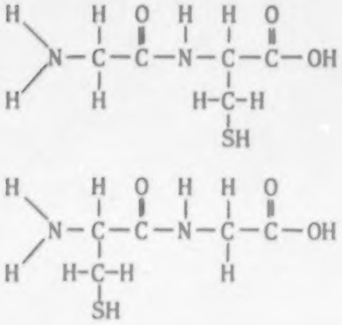
KEY--PROBLEM SET 17:

1. carboxyl group: b,c
   amino group: a,b
   primary amine: a,b
   amino acid: b
   ester: b
   saturated fatty acid: a
   unsaturated fatty acid: d
   amino acid: e
2. monosaccharide: f
   disaccharide: c
3. a. c and f
   b. e
   c. a, b and d

4.



5.



6. a and b.

	functional groups	
glycerol	hydroxyl	alcohol
glycine	amino, carboxyl	amino acid (organic acid)
lactose	hydroxyl*	carbohydrate
amylase	--	protein
starch	hydroxyl*	carbohydrate
acetic acid	carboxyl	organic acid
corn oil	--	fat

*Other groups are also present but are not discussed in the text.

c. corn oil

d. amylase

LESSON 18: PROTEIN REQUIREMENTS AND PROTEIN QUALITY

RATIONALE:

In ST-17, the chemistry of amino acids and proteins was considered. ST-18 is concerned with the importance of proteins in the diet.

OBJECTIVES:

The student will:

- state the importance of essential amino acids.

- define "complete protein" in terms of essential amino acids.
- state that proteins are necessary for replacing cells.
- determine the protein RDA for an individual, given age, body weight and a graph similar to the one in Section 18-1.
- describe the effect of age on the protein RDA.

SEQUENCE: ST-18; LA-12 (or reverse)

SUGGESTIONS:

1. ST-18 emphasizes the role of dietary amino acids as a source of body protein. You may wish to mention that amino acids are used in production of other nitrogenous body compounds. For example, the synthesis of the purines in DNA and RNA requires the amino acids glycine, glutamine and aspartic acid.

2. Students may wish to know what happens to excess dietary protein. Unlike fats and carbohydrates, proteins are not stored by the body in quantity. Excess amino acids are degraded. The nitrogen splits off and is excreted as urea, while the leftover organic acids (minus nitrogen) are converted to fat or carbohydrate or utilized as a source of energy.

3. The protein RDA is increased during pregnancy and lactation. Also, severe infections or surgery can result in a substantial loss of protein thus increasing the protein RDA.

To be rigorous, the protein RDA should consider how much a person should weigh rather than his actual weight. For example, suppose a person whose ideal weight is 75 kg begins to gain weight and reaches 150 kg. This person does not need twice as much protein daily as he did when he weighed 75 kg.

4. A possible optional project for students would be to "rate" their vegetable sources of proteins. This kind of activity might be useful for students who are vegetarians. If this option is taken, such students might design their own rating systems and report the results to the class.

5. The answer to the last italicized question on p. 102 is as follows.

$$315\ \text{lb}\left(\frac{1\ \text{kg}}{2.2\ \text{lb}}\right)\left(\frac{0.8\ \text{g}}{\text{kg-day}}\right) = 115\ \text{g/day}$$

LESSON 19: MINERALS AS NUTRIENTS

RATIONALE:

The need for carbohydrates, fats and proteins in the diet has been considered in ST-13 through ST-18. In ST-19, minerals are discussed as a fourth class of nutrients. This lesson describes the functions of minerals in the body with reference to the clinical effects of mineral deficiencies.

OBJECTIVES:

The student will:

- define "mineral" in the nutritional sense.
- list and state the main function for at least four minerals required in quantities of over 100 mg per day.
- state that nutritional anemia results from a dietary deficiency of iron.
- explain the relation between dietary iodine and goiter.
- define and list at least two "trace" minerals.

SEQUENCE: ST-19; LA-12 (or reverse)

SUGGESTIONS:

1. Some background information on minerals in nutrition is included below. More information on this subject is given in Section 21 and should be reviewed prior to teaching Lesson 19.

2. The nutrient analysis activity (LA-12) should be nearing completion about the time that this lesson is taught. When you have a general class discussion of LA-12, it would be a good idea to include as much of the relevant text material on the chemistry of proteins, fats and carbohydrates as possible.

INFORMATION ON MINERALS IN NUTRITION:

There are over 100 known elements. Eleven account for the bulk of living matter, while many of the remaining elements are found in plants and animals. The amounts range from trace concentrations that are barely detectable to up to several hundred mg per g body weight. Biological functions in animals have been established for about a dozen trace elements, such as fluorine, manganese, cobalt and copper. Conceivably, all naturally occurring elements may evantually be shown to have a significant influence in human nutrition.

The increased consumption of highly refined or "fabricated" foods, and human exposure to environmental contaminants such as mercury and lead have changed trace element nutrition in humans--the former often results in reductions in essential trace nutrients, while the latter increases our intake of trace minerals.

LESSON 20: (A) VITAMINS AND THEIR FUNCTIONS
(B) ANALYSIS OF VITAMIN C IN FRUIT JUICE

RATIONALE:

Vitamins compose the final major class of nutrients. ST-20 describes the functions of most of the vitamins and the clinical conditions that can result from vitamin deficiencies. In LA-20, the students analyze for vitamin C in fruit juice. This activity provides a vehicle for a quantitative error analysis based on concepts developed in Biomedical Mathematics. In addition, it reinforces the technique of titration.

OBJECTIVES:

The student will

- define "vitamin."
- summarize the steps that led to the discovery of at least one vitamin.
- list at least four vitamins and the symptoms of a deficiency of each of these vitamins.
- list at least four sources of error in the vitamin C analysis.

SEQUENCE: ST-20; LA-20 (or reverse)

SUMMARY:

1. Two points about vitamins A and D deserve to be added. First, these vitamins are measured in "International Units." These are not units of mass but are based on the biological activity of the vitamins in a laboratory animal, usually a rat. Secondly, these vitamins are not ingested *per se;* we ingest substances that are converted to these vitamins in the body.

2. Students might be interested in seeing the structural formulas and/or constructing models of some of the vitamins. Some of the chemically simple vitamins are shown on the following page.

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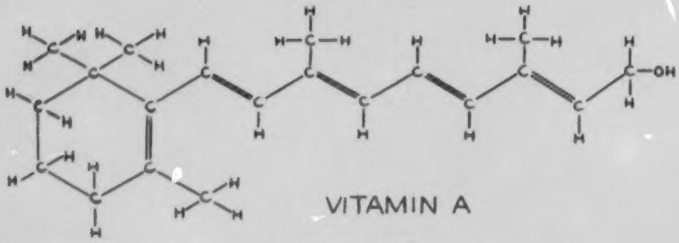
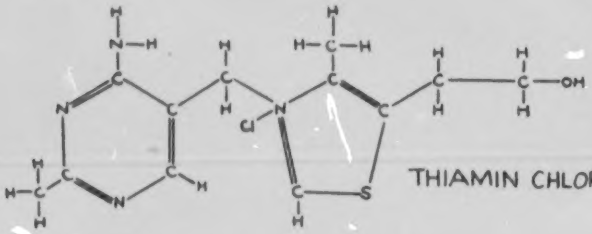
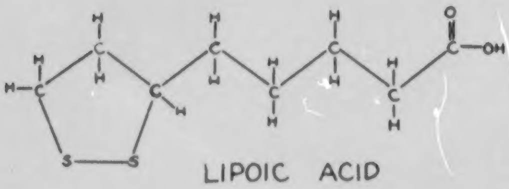
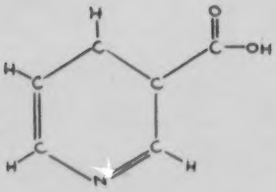
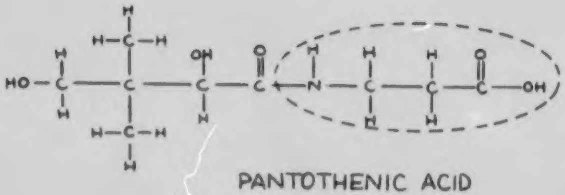
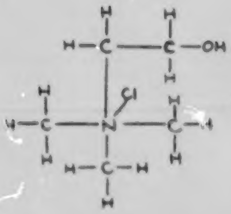
Vitamin	Comments
 VITAMIN A	Can be made with two kits. (Use springs for rings.) Note hydroxyl group.
 THIAMIN CHLORIDE	Can be made with two kits. (Use oxygen ball for sulfur.) Note hydroxyl group.
 LIPOIC ACID	Can be made with one kit. Note carboxyl group. This vitamin is required for one reaction in the breakdown of glucose to provide energy.
 NICOTINIC ACID (ONE OF 2 FORMS OF NIACIN)	Note carboxyl group.
 PANTOTHENIC ACID	Note hydroxyl groups, peptide link, carboxyl group. The part in dotted circle is contributed by an amino acid.
 CHOLINE CHLORIDE	Note alcohol group.

3. The primates, including man, and guinea pigs have something in common. They are unable to manufacture vitamin C within their own bodies. When deprived of vitamin C from dietary sources for a sufficient length of time, these animals will develop scurvy.

At the present time, scurvy is uncommon in the United States. It occurs chiefly in infants fed diets essentially limited to milk (a poor source of vitamin C). Adults with scurvy are generally starving, alcoholic, or nutritionally ignorant.

INFORMATION ON LABORATORY ACTIVITY 20:

TEACHING NOTES:

1. The purpose of this activity is twofold. First, the students measure the amount of ascorbic acid in fruit juices using a simple titrimetric procedure. Secondly, the uncertainties associated with each measurement are compiled so that the limits of error may be formally calculated in the mathematics class. The activity serves to reinforce the titration techniques introduced in Unit I, as well as nutritional concepts in the Science Text and error analysis in the Mathematics Text.

2. It is recommended that you read Supplementary Sections Y and Z of the Mathematics Text before beginning the activity.

3. Science and Mathematics schedules should be coordinated. Section Y of the Mathematics Text should be taught just before this activity. The Mathematics instructor should be informed if the activity takes two days, since Section Z cannot be taught until the activity has been completed.

4. The activity may be implemented in a variety of ways. The students may bring in their own fruits and compare different juices. It is advisable to avoid red-colored juices, since they might interfere with the red color of the dye. Fresh juice may be compared to bottled, frozen or synthetic products (such as "Hi-C," "Tang" and "Start"). Juice from the rinds of citrus fruits could be tested for ascorbic acid. A sample of fresh juice may be left out for two to three days (either at room temperature or refrigerated) to demonstrate that significant amounts of ascorbic acid may be lost due to oxidation.

5. The metaphosphoric acetic acid solution has the following composition.

metaphosphoric acid	$(HPO_3)_n$	1%
sodium metaphosphate	$(NaPO_3)_n$	2%
acetic acid	CH_3COOH	6%

None of these ingredients are harmful at these concentrations, and therefore the solution may be safely mouth-pipetted. If you have general reservations concerning the mouth-pipetting of acids, the students may use a pipetting bulb, syringe or 10-ml graduated cylinder for measuring this solution.

6. The students may doubt that it is possible to read a buret volume to within ± .01 ml. It may be desirable to point out that this degree of precision allows for a total range of .02 ml within which the reading must fall.

MATERIALS: (for 10 set-ups)

- 0.3 g sodium 2,6-dichloroindophenol
- 151 ml acetic acid, glacial
- 80 g metaphosphoric acid ($NaPO_3$, ~62%; HPO_3, ~36%)
- 1 g ascorbic acid powder
- samples of fruit juices
- 10 burets, 50-ml
- 10 pipets, 1-ml
- 10 pipets, 10-ml
- 10 beakers, 50-ml
- 20 beakers, 250-ml
- 10 beakers, 150-ml
- 10 funnels
- 10 ring stands
- 10 ring-stand clamps

PREPARATION OF REAGENTS:

Indophenol dye solution: Dissolve 0.30 ± .02 g of sodium 2,6-dichloroindophenol in 500 ml of hot tap water. Filter and dilute the filtrate to 3000 ml. Add a small quantity (approximately 1 ml) of glacial acetic acid so that the solution takes on a red color. (The dye can serve as an acid-base indicator as well as an oxidation-reduction indicator.) The solution may be stored up to 5 days without refrigeration.

Metaphosphoric acetic acid solution: Dissolve 80 ± 1 g of metaphosphoric acid in approximately 800 ml of water. Add 150 ± 2 ml of glacial acetic acid and dilute with water to a final volume of 2400 ml. The solution may be stored under refrigeration up to 12 days.

Ascorbic acid standard solution: Dissolve 1.00 g of ascorbic acid powder in water and dilute to a total volume of 1000 ml. The use of a 1000-ml volumetric flask is recommended to reduce uncertainty as much as possible. If a volumetric flask is not available, a 1000-ml graduated cylinder may be used. Typical uncertainty values associated with the preparation of the standard solution are listed on the following page. These values should be provided for the students' data sheets.

UNCERTAINTIES ASSOCIATED WITH THE PREPARATION OF THE ASCORBIC ACID STANDARD SOLUTION

BALANCE	
accuracy	± .010 g
scale-reading imprecision, initial	± .001 g
scale-reading imprecision, final	± .001 g
total absolute uncertainty	± .001 g
VOLUMETRIC FLASK, 1000-ml	
accuracy	± .60 ml
total absolute uncertainty	± .60 ml
GRADUATED CYLINDER, 1000-ml	
accuracy	± 5.00 ml
scale-reading imprecision	± 1.00 ml
total absolute uncertainty	± 6.00 ml

ANTICIPATED RESULTS:

A table is provided that lists the ascorbic acid content in a 6-oz serving of some common juices. The values have been compiled from Bowes and Church, Food Values of Portions Commonly Used, 11th edition, 1970. In all cases, the juices are unsweetened.

JUICE	FRESH*	FROZEN, DILUTED	CANNED or BOTTLED
apple	trace	trace	trace
grapefruit	68	68	53
grape (white)	trace	--	trace
guava	--	--	150
lemon	82	78	75
lemonade	--	12	--
lime	57	--	39
orange	89	80	71
pineapple	--	21	17
tangerine	55	48	39

*Values subject to seasonal variation.

The uncertainty associated with the endpoint of the titration is expected to be between ± 0.10 ml and ± 0.40 ml, depending upon the juice tested.

ANSWERS TO DISCUSSION QUESTIONS:

1. Since the metaphosphoric acetic acid does not affect the amount of ascorbic acid in the sample, the exact amount of solution is not critical to the procedure.

2. Many uncontrollable errors are possible. For example, the ascorbic acid in the reagent bottle may be stale and, consequently, impure. Or, the indophenol dye may react with other substances present in the sample. The concentration of the dye may change slightly from day to day due to oxidation.

LESSON 21: (A) VITAMINS AND MINERALS IN THE DIET
(B) DETERMINING THE RIBOFLAVIN CONTENT OF VITAMIN PILLS
(C) REVIEW

RATIONALE:

In ST-19 and ST-20 the functions of vitamins and minerals were considered. ST-21 focuses on several nutritional problems (i.e., vitamin deficiencies, the excess sodium-hypertension hypothesis, dietary sources of vitamins, hypervitaminosis). In LA-21 students analyze vitamin pills for riboflavin content. This activity illustrates the importance of fluorescence as an analytical tool.

OBJECTIVES:

The student will:

- list the two minerals most likely to be deficient in American diets and will suggest good food sources of each of these minerals.
- describe at least two pieces of evidence in support of the hypothesis that a high-sodium diet increases the risk of hypertension.
- list at least two good food sources for at least three vitamins.
- define and give an example of "hypervitaminosis."
- describe how fluorescence can be used to estimate the concentration of riboflavin in a solution.

SEQUENCE: ST-21; LA-21 (or reverse)

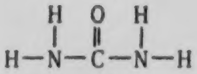
SUGGESTIONS:

1. This would be a good time for a review and quiz. Lesson 21 is the last of the nutritional chemistry lessons (Lessons 10 through 21). Lesson 22 begins a sequence of lessons on energy, metabolism and the diet.

2. You might give students a research problem involving one or more hypothetical diets. Their task would be to evaluate the diet(s) for any vitamin deficiencies. USDA Home and Garden Bulletin No. 72 would be useful for this purpose. It would not be a good idea to have students analyze their own diets for deficiencies because they will do this in Activity 29.

3. Students might be given case histories or descriptions of patients with severe vitamin or mineral deficiencies. They could be asked to determine the nature of the deficiency and also how to modify the diet to cure the patient.

4. Urea is used in LA-21. Students may be curious about its structure. It is



$$\mathrm{H-\overset{\overset{H}{|}}{N}-\overset{\overset{O}{\|}}{C}-\overset{\overset{H}{|}}{N}-H}$$

5. You may find an occasional discrepancy between food values listed in USDA Bulletin 72 and the Student Text. This occurs because we have sometimes used a different reference for our values.

6. There is a high school-level game available that may be useful in reviewing the properties of vitamins. It is called "Vitamins." For more information write to The Lawhead Press, Inc., 900 East State Street, Athens, Ohio 45701.

INFORMATION ON VITAMIN B_{12}:

Vitamin B_{12} is a cobalt-containing vitamin present in human cells. It is essnetial for normal functioning and acts as a coenzyme in metabolism.

Neither animals nor higher plants manufacture this important vitamin. It is made by lower organisms, mainly bacteria and fungi. (In fact, microbes are the commercial source of vitamin B_{12}.) Cows obtain vitamin B_{12} from bacteria in their rumen while chickens get this vitamin by pecking at the soil. This explains why their flesh is so rich in the vitamin.

Since vitamin B_{12} is found chiefly in animal products, vegetarians may suffer a deficiency. A good way for vegetarians to obtain vitamin B_{12} is by eating fermented products, especially soy products popular in Asia such as tofu. Kelp is another good food source of vitamin B_{12}. Although cheese is a fermented product it is not a good source of vitamin B_{12}. When the whey is removed in the cheese-making process, this essential vitamin is lost.

KEY--REVIEW SET 21:

1. Organic compounds contain carbon; inorganic compounds (with a few exceptions) do not. Organic: a, c, e; inorganic: b, d, f.

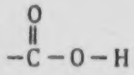
2. The attraction between a hydrogen atom of one molecule and a negatively charged atom of another molecule. Water, proteins.

3. a and c

4. a and b

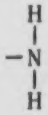
5. Identical: d; saturated: c; unsaturated: a, b, d

6. a. -O-H b.



$$-\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\mathrm{O}-\mathrm{H}$$

c.



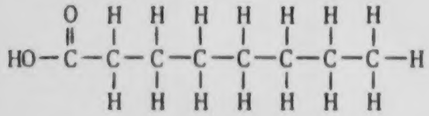
$$-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{N}}}$$

7. a. alcohol (hydroxyl group)
   b. ester
   c. amine (amino group)
   d. acid (carboxyl group)
   e. hydrocarbon

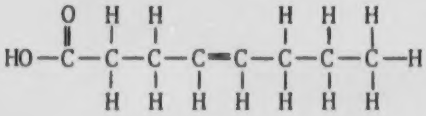
8. a

9. a, b, c

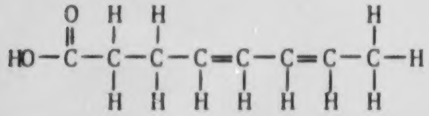
10.



$$\mathrm{HO}-\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\mathrm{H}$$



$$\mathrm{HO}-\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{H}}{\mathrm{C}}=\underset{\mathrm{H}}{\mathrm{C}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\mathrm{H}$$



$$\mathrm{HO}-\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\underset{\mathrm{H}}{\mathrm{C}}=\underset{\mathrm{H}}{\mathrm{C}}-\underset{\mathrm{H}}{\mathrm{C}}=\underset{\mathrm{H}}{\mathrm{C}}-\overset{\mathrm{H}}{\underset{\mathrm{H}}{\mathrm{C}}}-\mathrm{H}$$

The third fatty acid shown above is preferable because it is polyunsaturated. It will tend to reduce the cholesterol concentration in the blood.

11. a. an amino acid that must be supplied by the diet.

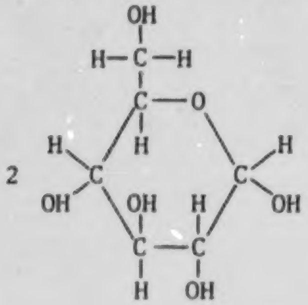
    b. a protein source that provides sufficient quantities of all essential amino acids.

12. a. true--hydrolysis

    b. false

c. false

d. true--dehydration synthesis

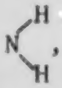
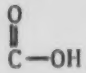
13. 

c. (carbohydrase); in the mouth stomach and intestines; they also occur elsewhere but this has not been discussed in the text.

14. Glucose is digested more rapidly than starch. This can cause hypoglycemia and may be associated with atherosclerosis.

15. c; f; citrus fruits, green peppers, onions, tomatoes

16. a, b, c, e, f, g

17. a. OH, , and  $\overset{O}{\overset{\|}{C}}-OH$

(Iodine may also be counted as a functional group.)

b. amino acid

c. iodine

INFORMATION ON LABORATORY ACTIVITY 21:

TEACHING NOTES:

1. The purpose of this activity is twofold: (1) to introduce the students to a laboratory method involving fluorescence under ultraviolet light, and (2) to have the students apply this technique to analyze for riboflavin in vitamin pills.

2. Anticipated time: two periods. Part I should take approximately 20 minutes and could be done during Lesson 18 or 19. Part II should take about 30 to 45 minutes. It is not absolutely essential that Part II be performed one day after Part I. The urea-vitamin solutions will keep for as long as 48 hours.

3. Most of the absorption peaks of riboflavin fall in the short-wavelength range of the UV spectrum, and lamps which produce these wavelengths are expensive. The lamps that we have specified are inexpensive, but they emit UV light of

longer wavelengths. In this wavelength range, small quantities of riboflavin will not fluoresce. Should you have access to a lamp that emits shorter UV wavelengths, you might attempt an analysis of foods for riboflavin. The procedure would be the same, except that standards with lower riboflavin concentrations would be needed.

4. A UV spectrophotometer, such as a Beckman DB, or a fluorometer could be used to make the method quantitative.

5. Students may be curious about the nature of fluorescence. Fluorescent light is electromagnetic radiation in the visible range emitted from some substances when they absorb radiation of certain specific wavelengths from another source. Typically, some of the energy from the absorbed radiation is converted to heat. Consequently, the light emitted is less energetic and is of longer wavelength. In this activity UV light (shorter wavelengths) is absorbed and visible light (longer wavelengths) is emitted.

6. The activity can be shortened by preparing the standard solutions yourself and limiting the number of different vitamin pills tested. It can be extended by having students test several different vitamin preparations.

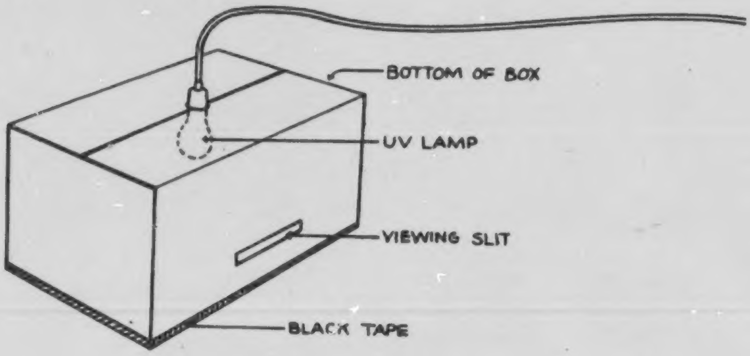
7. In order to avoid the expense of purchasing a number of different brands of vitamin pills, the students could be asked to bring in pills from home. They should each bring about 10 identical pills and a note listing the concentration of riboflavin in the pills. This information appears on the label. Plan to collect the vitamins in advance of the time scheduled for the activity, since you will need to set them out in containers labeled with appropriate code letters.

8. The directions call for students to make up the standard solutions. The number of students needed will depend on the number of testing stations you set up.

9. Each UV station will require the following materials: a cardboard box; a UV lamp with socket, cord and plug; black tape or construction paper; and one set of the four standards. The quantities given in the materials list assume four stations.

10. To prepare the viewing boxes, cut the flaps off of a cardboard carton. Turn the box upside down and reinforce the lengthwise seam on the bottom with masking tape. Cut a circular hole in the center of the bottom of the box just large enough to accept the threaded portion of the base of the UV lamp. On one long side of the box cut a viewing slit about 3/4" x 3". You may have to put

black tape or construction paper around the bottom of the box to keep the light that enters the box from outside at a minimum. The UV lamps should be 75-watt "blacklites." They may be obtained at most hardware stores.



11. The vitamin pills that are used for the standard solutions should all be the same. These pills should have a high riboflavin content so that the four standards that are made will have riboflavin concentrations ranging from about 2 to 16 mg/40 ml.

12. Vitamin pills that have a lot of red in their outer coating are not suitable for this activity. Too much red interferes with perception of the fluorescence. Also, vitamins with an outer gelatin capsule are not recommended since the capsule cannot be ground up.

13. While the UV lamps are on, check periodically so see that the cardboard is not being overheated. In our testing, however, we have found no evidence of burning or charring during lengthy periods of use.

14. It is probably a good idea to remind the students not to look directly at the UV lamps while they are on.

MATERIALS: (for 30 set-ups)

- viewing boxes (see TN #9 and #10)
- vitamin pills
- 400 g urea (Mallinckrodt #8642)
- 46 beakers, 50-ml
- 30 beakers, 150-ml
- 15 graduated cylinders, 100-ml
- 30 stirring rods
- 15 glass-marking pencils
- 10 mortars and pestles
- 15 balances
- 30 scoopulas
- 30 funnels
- filter paper, Whatman No. 1, 11 cm
- aluminum foil
- paper towels

PREPARATION OF REAGENT:

3.3 M urea solution, 2 liters: To 396 ± 5 g of urea add sufficient water to make 2 liters of solution.

ANTICIPATED RESULTS:

The results will vary according to the type of vitamin pill used for the standard solutions and the types of vitamin pills analyzed. We obtained the following data in our laboratory.

Solutions	Riboflavin Content
Standard #1	17.4 mg
Standard #2	8.7 mg
Standard #3	4.4 mg
Standard #4	2.2 mg
Unknown #1*	3.3 mg (midway between 4.4 and 2.2)
Unknown #2**	6.6 mg (midway between 4.4 and 8.7)

The estimated riboflavin content for Unknown #1 was 2.3 mg/pill. The value listed on the label was 2.0 mg/pill.

The estimated riboflavin content for Unknown #2 was 6.6 mg/pill. The value listed on the label was 6.0 mg/pill.

ANSWERS TO DISCUSSION QUESTIONS:

1. A qualitative test is used to determine whether or not a specific substance is present in a sample. It gives no information on the quantity of the substance. A semi-quantitative test gives a rough estimate of the quantity of the substance. Quantitative tests give more precise information.

2. Vitamin pills were used to provide samples with a high enough riboflavin content to be detectable.

3. The urea solution was used because riboflavin is more soluble in a urea solution than in water.

4. Our results compared quite favorably with the information given on the vitamin labels. If the directions are followed carefully, students should obtain a good estimate of the riboflavin content of a pill. Differences may be attributable to the semi-quantitative nature of the procedure.

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*BEVITRIN, Formula No. 21, Vitamin Specialists Co., 5521-25 Wayne Ave., Philadelphia, Pennsylvania, 19144.

**HI-BEE-CEE, Formula No. 11 (same manufacturer).

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LESSON 22: (A) ENERGY

(B) EVIDENCE OF CHEMICAL REACTIONS

RATIONALE:

So far the Nutrition Unit has explored essential nutrients in the diet, and the foods that contain them. Since the food we digest is utilized for energy to heat the body, move muscles and build molecules, it is appropriate now to consider energy. In addition, to prepare for the study of metabolism, which is to be presented shortly, students should be acquainted with the role of energy in chemical reactions. This lesson presents the concept of energy in general terms and also introduces its role in chemical reactions. The next two lessons deal with the measurement of energy released or absorbed in chemical reactions and the role of energy in nutrition. LA-22 considers how to detect whether or not a chemical change has occurred. It is designed to prepare the students for a study of heats of reaction.

OBJECTIVES:

The student will:

- list five forms of energy.
- distinguish between kinetic energy and potential energy.
- distinguish between heat and temperature.
- define calorie and kilocalorie, and use the definitions to calculate the amount of heat required to raise or lower the temperature of a given mass of water by a given number of degrees Celsius.
- define chemical energy.
- describe the role of energy in the formation and breaking of chemical bonds.
- state whether a chemical reaction has occurred, through observations of the effects of mixing substances.

SEQUENCE: ST-22; LA-22

SUGGESTIONS:

1. It is possible to demonstrate the difference between kinetic energy (the energy of motion) and potential energy (stored energy), by performing the following seemingly unrelated demonstrations, which all involve conversion from

potential to kinetic energy. Have the students name the form of potential and kinetic energy in each case.

	Potential Energy	Kinetic Energy
1. release a stretched rubber band	elastic (just before release)	motion
2. light a match	chemical (in match)	heat
3. push a book or pencil off edge of desk	gravitational	motion
4. release a compressed spring	elastic	motion
5. lift a hand	chemical (substances in muscle tissue)	motion
6. let an iron object move toward a magnet	magnetic	motion
7. pick up a tissue with a comb after running the comb through hair	electric	motion (of tissue)

In addition, one form of kinetic energy can be changed into another:

	First Form	Second Form
1. heat hands by rubbing them	motion	heat
2. clap hands	motion	sound (motion of air molecules)

Some of the above activities actually involve multiple energy changes. For example, in striking a match, motion of the match is converted to heat of friction, which ignites the match. During burning the chemical potential energy is converted to heat (kinetic energy) and light (radiant energy). Similarly, energy of motion in rubbing a comb is converted to electric potential energy in the comb, which is converted to motion of the tissue.

2. You may wish to lead a discussion of the different ways in which heat is generated. Have the students identify which ones involve a change from potential energy into heat, such as from chemical potential energy in burning, nuclear potential energy in the sun. Other ways to generate heat involve a change from

another form of kinetic energy into heat, such as from motion in friction-produced heat or electric current into heat.

3. You could present a diagram of the electromagnetic spectrum and discuss light and other forms of radiant energy. Point out that X-rays, IR (infrared) rays and UV (ultraviolet) rays all have some clinical applications, such as skin-disease treatment, heat lamps, X-ray treatment of cancer, etc. [Light energy was not emphasized in this lesson because it will be treated in some depth in later lessons on vision (Unit IV).]

4. To clarify the distinction between heat and temperature, you could ask, "Which has more heat, a bathtub of water at 50 °C or a cup of water at 50 °C?" (Answer: the bathtub.) "Which has a greater temperature?" (Answer: they are the same.) Heat is the total kinetic energy in a mass. Temperature is a measure of the average kinetic energy of the individual molecules, atoms or ions in the mass.

5. Students will need food samples to test in LA-23. The activity is designed so that students bring in food samples from home. The types of foods required are listed in LA-23, Part II, Step 1 (p. 78).

INFORMATION ON LABORATORY ACTIVITY 22:

TEACHING NOTES:

1. The purpose of this activity is to provide the students with guidelines for identifying evidence of chemical change. The experience with exothermic and endothermic reactions serves as a prelude to both ST-23 and LA-23.

2. Anticipated time: one period.

3. The activity may be shortened by decreasing the number of tests performed.

4. The activity may be lengthened by allowing students to test combinations of other available reagents. Tests based on any of the earlier laboratory activities are possibilities. Having the class judge the outcome of demonstrations is another option. For example, adding conc. H_2SO_4 to a beaker containing a small amount of sugar causes the formation of foamy black carbon. Another possibility is to dip a glass rod in ammonium hydroxide solution and hold the rod over conc. HCl. Invisible HCl and NH_3 vapors will react to form dense white fumes of NH_4Cl. A final dramatic possibility is to add a small volume of ammonium hydroxide solution to a dilute solution of $CuSO_4$. A pale blue precipitate of $Cu(OH)_2$ will form. In addition a very dark solution forms due to production of $Cu(NH_3)_4^{+2}$.

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5. A brief review of the phases of matter may be useful.

6. Any grade of chemical reagent is suitable, since the reactions are qualitative.

7. The notation iron "(II)" sulfate is introduced without comment in this activity. You may wish to explain the difference between the two oxidation states of iron at this time. Refer to any college inorganic or general chemistry textbook for more background on these two states of iron.

MATERIALS: (for 15 set-ups)

0.2 g phenolphthalein
35 ml HCl, conc.
2.8 g acidified iron (II) sulfate ($FeSO_4 \cdot 7H_2O$)
0.32 g potassium permanganate ($KMnO_4$)
0.18 g sodium chloride ($NaCl$)
0.36 g potassium bromide (KBr)
35 g ammonium chloride (NH_4Cl)
50 pellets sodium hydroxide ($NaOH$)
35 g sodium acetate ($NaC_2H_3O_2$)
25 g sodium bicarbonate ($NaHCO_3$)
1.75 g manganese dioxide (MnO_2)
35 g potassium chlorate ($KClO_3$)

15 gas burners
30 test tubes, 16 x 125 mm, Pyrex
15 test-tube racks
15 test-tube holders
15 rubber stoppers, #00
15 pipets, 10-ml
15 beakers, 150-ml (or any small size)
15 scoopulas
15 medicine droppers
15 glass-marking pencils
matches
15 wooden splints
paper tares

PREPARATION OF REAGENTS:

6 M HCl solution, 70 ml: Add 35 ± 3 ml conc. HCl to sufficient water to make 70 ml.

Take 0.5 ± .05 ml of this solution and dilute to 30 ml with water. (This provides the 0.1 M HCl needed in the next preparation.)

0.1 M acidified iron (II) sulfate ($FeSO_4 \cdot 7H_2O$) solution, 100 ml: 2.8 ± .1 g $FeSO_4 \cdot 7H_2O$ + sufficient water to make 100 ml. Add 0.1 M HCl a drop at a time until an acid reaction is obtained with litmus.

0.1 M NaCl solution, 30 ml: 0.18 ± .01 g NaCl + sufficient water to make 30 ml.

0.1 M KBr solution, 30 ml: .36 ± .01 g KBr + sufficient water to make 30 ml.

0.1 M $KMnO_4$ solution, 20 ml: .32 ± .01 g $KMnO_4$ + sufficient water to make 20 ml.

phenolphthalein solution, 20 ml: Dissolve 0.2 ± .01 g phenolphthalein in 10 ml of ethyl alcohol. Dilute to 20 ml with water.

Add about 1.75 g of MnO_2 to 35 ± .01 g of $KClO_3$ and mix thoroughly. The MnO_2 catalyzes the reaction in Procedure Step 14.

ANTICIPATED RESULTS:

Step Number	Reactants Involved	Observations	Chemical Reaction? (yes or no)
3	water + 6 M hydrochloric acid	none	no
4	hydrochloric acid solution + phenolphthalein solution	cloudiness	no
6	water + sodium hydroxide	NaOH dissolves; tube gets warmer $NaOH \rightarrow Na^+ + OH^-$	yes
7	sodium hydroxide solution + phenolphthalein solution (HPh)	Solution turns pink $HPh + Na^+ + OH^- \rightarrow H_2O + Na^+ + Ph^-$	yes
9	ammonium chloride + water	NH_4Cl dissolves; tube gets cooler $NH_4Cl \rightarrow NH_4^+ + Cl^-$	yes
10	sodium acetate + water	Sodium acetate (NaAc) dissolves; tube gets cooler $NaAc \rightarrow Na^+ + Ac^-$	yes
11	sodium bicarbonate + hydrochloric acid	Bubbles vigorously; gas given off $NaHCO_3 + H^+ \rightarrow Na^+ + H_2O + CO_2$	yes
12	acidified iron (II) sulfate + potassium permanganate	Color changes to yellowish $3\ Fe^{++} + MnO_4^- + 4\ H^+ \rightarrow 3\ Fe^{+++} + 2\ H_2O + MnO_2$	yes

(continued)

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13	potassium bromide + sodium chloride	none	no
14	potassium chlorate + heat	Oxygen given off; glowing splint bursts into flame $2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$	yes

ANSWERS TO DISCUSSION QUESTIONS:

1. Step 6.
2. Steps 9, 10. (In Step 14, heat was absorbed from the flame.)
3. Steps 11, 14.
4. Steps 7, 12, 14.
5. Change in temperature, change in color, formation of precipitate or gas.

It is a moot question whether a change of state occurs when a solid dissolves or precipitates out. If students answer Reactions 4, 6, 9 and 10 under Question 3, this should not be considered incorrect. They should, however, be consistent. For example, if they gave the above answers, their sample data sheet should record "chemical reaction" for each of these numbers.

LESSON 23: (A) HEAT OF REACTION
(B) MEASURING CALORIES IN FOODS

RATIONALE:

ST-22 presented the concept of energy and explained its role in the formation and breaking of chemical bonds in reactions. This lesson extends that concept to include the net amount of energy released or absorbed during a chemical reaction, called the heat of reaction. Heats of reaction permit an understanding of how different foods release different amounts of energy in chemical reactions in the body. The Law of Conservation of Energy, which is basic to an understanding of energy, is presented. In LA-23 breaking down food by combustion illustrates the release of energy from food.

OBJECTIVES:

The student will:

- define the terms "exothermic" and "endothermic."
- define the term "heat of reaction" and incorporate it in a balanced chemical equation.
- determine the heat of reaction per quantity of reactant when given a balanced chemical equation that includes the heat of reaction.
- state the Law of Conservation of Energy.
- outline the general procedures used to determine the heat of reaction experimentally.

SEQUENCE: ST-23; LA-23

SUGGESTIONS:

1. You may wish to show the students how to solve a "calorimetry" problem that parallels the calculations required in LA-23. For example, in a calorimetric investigation it is found that 12 grams of reactant raise the temperature of 100 ml of water by 18 °C. How much heat is generated, in calories, per gram of reactant?

Answer; 100 ml of water has a mass of 100 grams. The total energy released is 100 x 18 = 1800 cal, or 1.8 kcal. The energy released per gram is $\frac{1800}{12}$ = 150 cal per gram, or 0.15 kcal per gram.

2. Students will perform calorimetry on different foods in the laboratory. You may wish to present a short demonstration first. You might burn a candle or alcohol lamp for a minute or two under a beaker with a known amount of water. Measure the rise in water temperature. The fuel should be weighed before and after burning to find how much has burned. The heat generated, in calories, is calculated from the data as follows. If the burning of x grams of fuel changes the temperature of m ml of water by ΔT °C the amount of heat given off is $m\Delta T$ calories. The heat generated per gram of fuel is $\frac{m\Delta T}{x}$ calories per gram.

It is possible to compare the quantity of heat given off per gram of candle wax with that of a gram of alcohol. The heat released by a gram of paraffin is almost twice that released by a gram of alcohol.

3. Since the text material for this lesson is complex, a synopsis is provided on the following page.

a. All substances that have chemical bonds contain stored energy in the bonds. In a chemical reaction, rearranging bonds results in products containing a different amount of energy (either more or less) than the reactants. There is thus either a net gain or a net loss of energy during a reaction.

b. The energy lost or gained in a chemical reaction is generally treated as heat. If heat is lost, products end up with less energy than the reactants and the reaction is called exothermic. Conversely, if heat is absorbed, the products end up with more energy than the reactants and the reaction is called endothermic.

c. The quantity of heat released or absorbed is called the heat of reaction, ΔH. ΔH is the difference between the energy of products and reactants. $\Delta H = H_{products} - H_{reactants}$. When heat is absorbed, ΔH is positive because the products have more energy than did the reactants. Conversely, when heat is lost, ΔH is negative because the reactants contained more energy than the products.

d. ΔH is usually written as ΔH_r. The units for ΔH_r are $\frac{\text{kcal}}{\text{mole}}$. For example, consider the equation

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + 673.0\ \text{kcal}$$

ΔH_r is negative because heat is lost from the molecules during the reaction. (See Answer 1b, Problem Set 23.) ΔH_r is $-673.0\ \frac{\text{kcal}}{\text{mole sugar}}$ and $\frac{-673}{6}\ \frac{\text{kcal}}{\text{mole } O_2,\ CO_2 \text{ or } H_2O}$.

e. The Law of Conservation of Energy states that energy can neither be created nor destroyed. Examples are given in the student Text.

f. Heats of reaction are additive. When products form in a single reaction, the heat of reaction is the same as when the process occurs in two or more steps with intermediate products. The example of the oxidation of maltose either in one or in two steps is given in the text.

4. It is suggested that Problem Set 23 be worked with the entire class in a stepwise fashion approximately as follows. This is recommended because of the complexity of the material.

KEY--PROBLEM SET 23:

1. a. Since ΔH_r is negative, $H_{products} - H_{reactants}$ is negative, so the products have less energy than the reactants. This indicates a net loss of heat in the reaction. The reaction is thus exothermic.

b. When ΔH_r is negative, the number is written as positive on the right side of the equation. This indicates that heat is generated.

$$H^+ + HCO_3^- \rightarrow H_2CO_3 + 1.82 \text{ kcal}$$

2. a. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

b. Since heat is released, the reaction is exothermic. Combustion reactions are exothermic.

c. $\Delta H_r = -210.8$ kcal/mole of methane. It is negative because the heat is energy lost by the molecules.

d. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O + 210.8$ kcal

The heat of reaction is written as positive and on the right side to show it is generated in the reaction.

e. The heat generated is energy lost during the reaction. Therefore the products have less energy in their bonds than reactants.

3. a. Since the product, water, contains fewer kcal than the reactants, energy is lost in the reaction. The reaction is exothermic.

b. The heat of reaction is -13.36 kcal. It is negative because the molecules lose energy in the reaction.

4. a. Since ΔH_r is positive, the molecules gain energy during the reaction. The reaction is endothermic.

b. When galactose is first changed to glucose, 2.3 kcal/mole are absorbed. Then 673.0 kcal/mole are released in the oxidation of glucose, so a net of 670.7 kcal are released. Since heats of reaction are additive, -2.3 + 673.0 = 670.7 kcal/mole are released if the reaction occurs directly in one step.

c. 1 mole galactose = 180 g galactose

$$\frac{670.7 \text{ kcal}}{1 \text{ mole}} = \frac{670.7 \text{ kcal}}{180 \text{ g}} = 3.73 \frac{\text{kcal}}{\text{g}}$$

5. a. $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

b. $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O + 2606$ kcal

The energy released is 2 x 1303 kcal because there are 2 moles of octane in the balanced equation. It is written with a positive sign on the right side of the equation to show that heat is generated in the reaction.

c. Since heat is released, the reaction is exothermic.

d. If 900 kcal/mole of octane are converted to heat, the remaining energy available is 1303 - 900 = 403 kcal/mole of octane.

e. The Law of Conservation of Energy.

INFORMATION ON LABORATORY ACTIVITY 23:

TEACHING NOTES:

1. The purpose of this activity is to illustrate the use of a calorimeter for comparison of the energy content of different foods. The heat of a neutralization reaction similar to one that occurs in the body is also demonstrated.

2. Anticipated time: one to two periods (may be extended).

3. For Part I, it is important to prepare the HCl and Na_2CO_3 solutions in advance so that they will be at the same temperature when the activity begins. When Na_2CO_3 is dissolved, the temperature falls. Leaving the two reagents at room temperature for a few hours assures that their temperatures will be the same.

4. Have some extra 16-oz paper cups on hand to allow for mistakes. The cups should be large enough so that when shortened by students to a height of 10 cm by cutting their lower ends, they will slip easily over a 50-ml beaker. I.e., after being shorted to a height of 10 cm, their bottom diameters should be 4.8 cm or larger. If necessary, cups may be shortened to 9 cm to achieve this diameter.

5. The caloric values of food determined in the activity range from 20 to 80 per cent of values in printed tables. The values are low primarily because the calorimeters designed for this activity are crude and don't trap all the heat from burning food. Nevertheless, comparisons between different kinds of food can be made.

6. The activity may be broken off at any point and resumed later. Part I may be eliminated to provide more time for food measurement or to shorten the activity.

7. Each group should test and compare two foods: fat or oil, plus one other food type, for caloric energy. Different groups' values for the same food may not be the same because of variations in the set-ups, such as the size of the holes in the calorimeter cups and the heights of the cups. It may be of interest to discuss sources of variation in team results on the same food.

8. The likelihood of a paper calorimeter cup catching fire is small. However, you may want to "be prepared." The work can be done near sinks or large containers of water kept handy.

9. Styrofoam cups may be used instead of paper cups, but can only be used with small flames, such as from fat and oil candles. With the large flames produced by peanuts and other solid foods, styrofoam tends to catch fire. The same precaution applies to small paper cups instead of the recommended large ones.

10. It is not recommended that thermistors be used in Part I, because they may be damaged by the acid. (You may wish to caution the students to be gentle with mercury thermometers when they stir with them in Part I.) A BIP thermistor may be used in Part II by suspending it in the center of the water in the flask.

11. Optional activities include the following.

a. A small alcohol lamp may be used with the calorimeter to measure the caloric value of alcohol.

b. Heat given off from the oxidation of iron may be demonstrated by placing wet steel wool in a thermos bottle and stopping it with a one-hole stopper that has a thermometer through it. The same set-up with wet lawn clippings or plant matter may be used to show the heat produced during the decay of plants. In either case, a control thermos with a stopper and thermometer but no iron or plants should be set up.

c. Results of Part I can be compared with the heats of neutralization of HCl with .6 M $NaHCO_3$ and .6 M NaOH. The heat released in the first case would be so small as to be undetectable with the apparatus used, while the reaction between HCl and NaOH releases a great deal of heat.

MATERIALS: (for 15 set-ups)

Part I:

83 ml hydrocholoric acid, conc. (HCl)

137 g sodium carbonate ($Na_2CO_3 \cdot 10H_2O$)

15 graduated cylinders, 100-ml

30 beakers, 50-ml

15 beakers, 250-ml

15 thermometers

15 small styrofoam cups

15 glass-marking pencils

Part II:

30 food samples
15 beakers, 50-ml
15 Erlenmeyer flasks, 250-ml
15 graduated cylinders, 100-ml
15 thermometers
15 to 20 large (16-oz) paper cups
15 razor blades
15 pieces of bare wire, 3 cm long
aluminum foil
string
clay
15 spoons or scoopulas
15 stirring rods
15 balances
matches, 15 books
3 to 5 scissors
paper towels

PREPARATION OF REAGENTS:

1 M hydrochloric acid, 1 liter: Add 83 ± 2 ml conc. HCl to sufficient water to make 1 liter.

0.6 M sodium carbonate solution, 800 ml: 137 ± 2 g $Na_2CO_3 \cdot 10H_2O$ + sufficient water to make 800 ± 5 ml.

ANTICIPATED RESULTS:

PART I:

An increase of 0.9 to 1.3 °C was observed. For an increase of 1.3 °C, $H = (1.3)(90) = 117$ calories.

$$\text{calories per mole of } Na_2CO_3 = \frac{117 \text{ cal}}{0.04 \text{ liter} \times 0.6 \text{ mole/liter}} = 4,875 \frac{\text{cal}}{\text{mole}}$$

or 4.875 kcal/mole. $\Delta H_r = -4.875$ kcal/mole Na_2CO_3.

PART II:

Anticipated results vary from 20 to 80 per cent of the values given in food tables (see Teaching Note 2). The following sample data illustrate this. Bear in mind that food tables often don't list values in calories per gram, and also that they list in Calories (capital C) which are kilocalories.

Food	Anticipated Results (calories/g)	Bowes and Church (calories/g)
Lard	3500-6200	9000
Solid Vegetable Fat	3300-5400	9000
Butter	3500-5700	7140
Oil	3200-5700	9000
Popcorn	1200-2000	3857
Peanut	2800-3800	5700
Cracker	2500	4000
Potato Chip	1200-1800	5400

ANSWERS TO DISCUSSION QUESTIONS:

1. Foods contain more energy in their chemical bonds before they are burned.

2. The reactants had more energy. The reaction was exothermic.

3. Fats and oils generally provide the most cal/g.

4. Differences between student results and values given in printed tables are due mainly to heat loss from the calorimeter. This includes heat loss through holes in the cup, heat loss to and through the cup and heat loss to and through the flask. Insufficient oxygen may also be a source of error.

5. The more fat, the higher the caloric content of a food. This is the case because fat provides 9 Cal/g while carbohydrate and protein each provide 4 Cal/g.

6. The body releases food energy by non-combustible chemical reactions, as in Part I.

7. The bomb is surrounded by water so that essentially all the heat generated is trapped by the water. There is sufficient oxygen to assure complete combustion.

LESSON 24: (A) FOOD, ENERGY AND METABOLISM

(B) CALCULATING THE DAILY ENERGY EXPENDITURE

RATIONALE:

One of the long-range goals of Unit II is for students to be able to plan an optimal diet. In Activity 24, the students determine the total amount of energy they expend in a given day. The data are needed for planning the optimal diet in Activity 31.

In ST-24 the discussion of chemical energy begun in ST-22 is extended to consider the energy content of several nutrients (fats, proteins and carbohydrates). The concepts of metabolism and basal metabolic rate (BMR) are then introduced and related to medicine in preparation for a more detailed treatment of the release of energy from glucose during cell respiration.

OBJECTIVES:

The student will:

- calculate the energy per gram released by complete oxidation of either a fat or sugar when given a chemical equation including the heat of reaction.
- calculate his or her energy expenditure for a typical day.
- define the terms metabolism, metabolic rate and basal metabolic rate.
- give an example of a medical condition that may be detected by performing a BMR test.

SEQUENCE: ST-24; Activity 24

SUGGESTIONS:

1. Different usages of the word "calorie" may be a source of confusion. One nutritionist's calorie = 1 Cal = 1 kilocalorie = 1000 calories. Food tables commonly use nutritionist's calories, written as Cal, or sometimes even written as calorie.

2. You may wish to try out the following two questions on your class.

a. How can the number of calories a person expends while performing a specific activity be determined in a laboratory? (Answer: (1) measure oxygen consumption, (2) correct it to STP (0 °C and 1 atm) using the gas laws, and (3) multiply by 5 Cal/liter $)_2$, the value for an average diet.)

b. Use the equation for the oxidation of a fat in Section 24-1 to find the Cal/liter of oxygen for fat oxidation. (Answer: $\frac{7657 \text{ Cal}}{72.5 \text{ moles } O_2} \cdot \frac{1 \text{ mole } O_2}{22.4 \text{ liters } O_2}$ = 4.7 Cal/liter O_2.)

This might be a good opportunity to reinforce the earlier treatment of the gas laws. According to Charles' Law, $\frac{V}{T} = \frac{V'}{T'}$

For T' = 25 °C:

$$\frac{22.4 \text{ liters}}{273\ ^\circ\text{K}} = \frac{V'}{298\ ^\circ\text{K}}$$

$$V' = \frac{(22.4)(298)}{273}$$

$$\approx 24.45 \text{ liters}$$

Thus a more rigorous solution of b would utilize the value of 24.45 l rather than 22.4 l.

$$\frac{7657 \text{ Cal}}{72.5 \text{ moles } O_2} \cdot \frac{1 \text{ mole } O_2}{24.45 \text{ liter } O_2} = 4.32 \frac{\text{Cal}}{\text{liter } O_2}$$

KEY--PROBLEM SET 24:

1. a. 44 amu
   b. 31 amu
   c. 121 amu

2. a. exothermic
   b. 342 amu
   c. approximately 3.95 Cal; yes

INFORMATION ON ACTIVITY 24:

TEACHING NOTES:

1. In this activity, the students have an opportunity to calculate the amount of energy expended during their daily activities. The results will be compared to their daily caloric intake in Activity 29. This worksheet is the first of a group of activities (see also Activities 29, 30 and 31) dealing with ideal weight and optimal diet.

2. Anticipated time: one to two periods.

3. "Active exercies" and "Very strenuous exercise" may be distinguished as follows. A moderate game of tennis or similar activities should be considered as active exercise. Very strenuous exercise refers to the kind of sustained activity that is engaged in when one is training as a runner or a swimmer. It should be emphasized that the energy expended during more active forms of exercise depends upon the degree of exertion. For example, a game of volleyball might involve a rate of expenditure of as little as 4 or more than 7 Cal/kg-hr, depending upon how it is played.

4. Students who experience difficulty with the calculations may be referred to Mathematics Problem Set 13, Unit II, for problems of a similar nature.

LESSON 25: CELL RESPIRATION--AN INTRODUCTION

RATIONALE:

In Sections 22 to 24, the concept of energy and especially chemical energy is developed. In ST-24 the relation between energy and the body is introduced. St-25 probes into the metabolic pathways by which the chemical energy in nutrients is released and used to produce ATP. The importance of ATP is suggested here and will be emphasized in ST-28 after the concept of equilibrium is considered. Activity 25 uses a board game to simulate and review cell respiration. This activity is designed to extend over several periods and Part III of the game covers material treated in ST-26.

OBJECTIVES:

The student will:

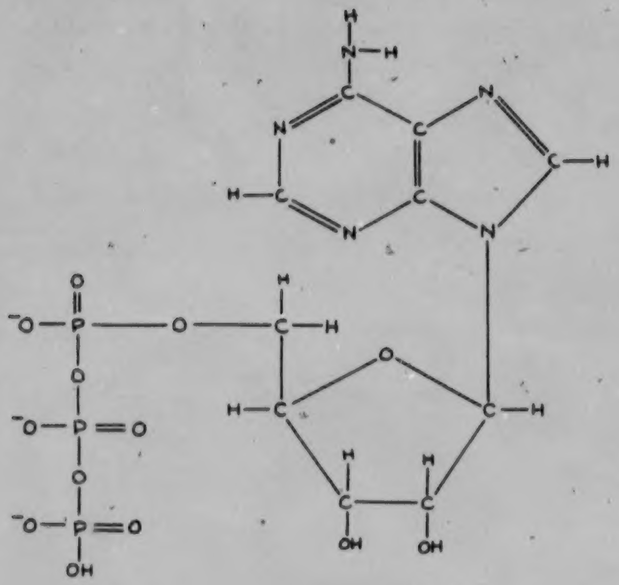
- distinguish between pulmonary respiration and cell respiration.
- write a balanced equation for the complete oxidation of glucose and explain how the oxygen and carbon dioxide shown in the equation are related to cell respiration.
- define metabolic pathway.
- state the structural difference between ATP and ADP and the significance of the extra phosphate group in ATP.

SEQUENCE: ST-25; Activity 25

SUGGESTIONS:

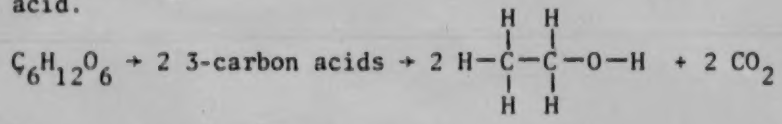
1. Students may wish to construct molecular models of ADP and ATP. You can point out that the five-membered ring with carbons and oxygen is the monosaccharide ribose. The two fused nitrogen-containing rings together with ribose constitute adenosine (the "A" in ATP). The phosphate groups are often shown as on p. 151 of the Student Text. However, it would be more correct to visualize these groups as ionized. (See figure on following page.)

2. The process of glycolysis can be easily demonstrated by adding some Brewer's yeast to a dilute (1 to 2%) glucose solution. In about a day bubbles will be visible. You can show that these bubbles are CO_2 by passing them through a limewater solution; a white $CaCO_3$ precipitate forms.



ATP (showing ionized phosphate groups).

The yeast demonstration is actually fermentation. Glucose is converted to pyruvic acid as in human glycolysis, but is then converted to ethyl alcohol rather than lactic acid.



$$C_6H_{12}O_6 \rightarrow 2\ \text{3-carbon acids} \rightarrow 2\ \mathrm{H{-}\overset{H}{\underset{H}{C}}{-}\overset{H}{\underset{H}{C}}{-}O{-}H} \quad + 2\ CO_2$$

(glucose) (pyruvic acid) (ethyl alcohol)

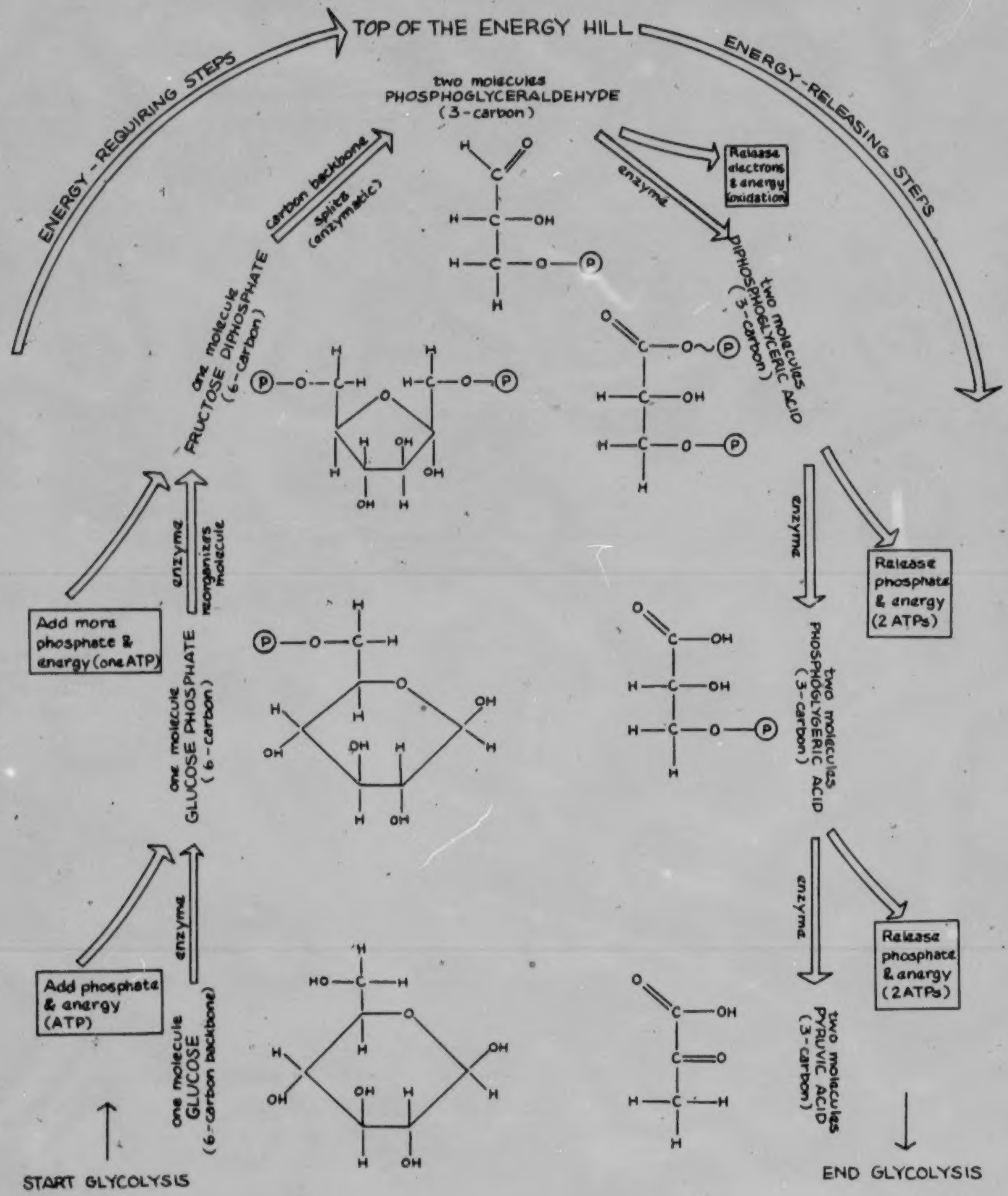
3. A more detailed scheme of glycolysis is shown on the following page.

4. A college-level metabolism game is available and includes a chapter explaining that game. A copy may be obtained for about five dollars. It was published in the Laboratory Manual, Involvement in Biology Today, CRM Books, Del Mar, Calif., 1972.

There is also a modestly priced game ($2.95 plus shipping) on cell physiology that you may find useful. It includes the concepts of active transport and diffusion. The game is called "The Cell Game" and is available from Telecote Press, Inc., P.O. Box 217, Glenwood, New Mexico, 88039.

5. You may wish to expand the treatment of cell respiration to include the Krebs cycle and oxidative phosphorylation. Some supplementary Student Text on these subjects follows, and you may wish to make copies of this material for interested students. This supplement is written in the style of ST-25 and provides a more detailed treatment of the material presented in ST-25. It was decided not

to include this supplement in the Student Text because it contains more detail than is necessary for the purposes of this course.


TOP OF THE ENERGY HILL
ENERGY - REQUIRING STEPS
ENERGY-RELEASING STEPS
two molecules PHOSPHOGLYCERALDEHYDE (3-carbon)
Release electrons & energy (oxidation)
enzyme
carbon backbone splits (enzymatic)
one molecule FRUCTOSE DIPHOSPHATE (6-carbon)
two molecules DIPHOSPHOGLYCERIC ACID (3-carbon)
enzyme
reorganizes molecule
Add more phosphate & energy (one ATP)
one molecule GLUCOSE PHOSPHATE (6-carbon)
enzyme
Release phosphate & energy (2 ATPs)
two molecules PHOSPHOGLYCERIC ACID (3-carbon)
enzyme
Add phosphate & energy (ATP)
one molecule GLUCOSE (6-carbon backbone)
enzyme
Release phosphate & energy (2ATPs)
two molecules PYRUVIC ACID (3-carbon)
START GLYCOLYSIS
END GLYCOLYSIS

SUPPLEMENT TO ST-25:

25-6 Once Around the Krebs Cycle

What is accomplished by the Krebs cycle?

You may recall that the molecular process of respiration can be summarized in one equation.

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{energy} \tag{5}$$

Thus far, we have seen how glycolysis leads to a partial breakdown of glucose into 3-carbon compounds and to the storage of energy as ATP. Yet we have not brought O_2 and CO_2 into the picture and there is much useful energy left in pyruvic acid. In the reactions to follow more energy will be released and "captured," and O_2 and CO_2 will be brought into the action. Most of the energy in glucose is released after pyruvic acid is formed.

The breakdown or degradation of pyruvic acid involves a metabolic pathway named the Krebs cycle after the biochemist who discovered it. The main steps of the cycle are shown in Figure 4.

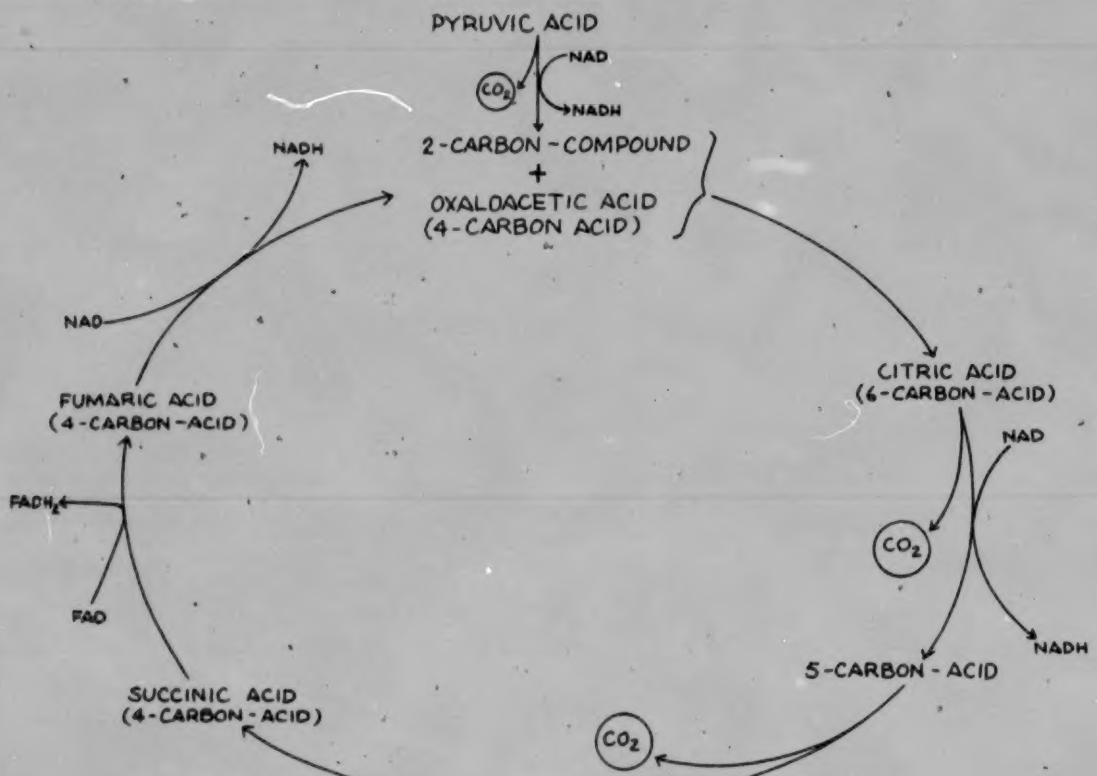

PYRUVIC ACID
NAD
CO₂
NADH
2-CARBON-COMPOUND
+
OXALOACETIC ACID
(4-CARBON ACID)
NADH
NAD
CITRIC ACID
(6-CARBON-ACID)
NAD
CO₂
NADH
5-CARBON-ACID
CO₂
NAD+ADP
NADH ATP
SUCCINIC ACID
(4-CARBON-ACID)
FAD
FADH₂
FUMARIC ACID
(4-CARBON-ACID)

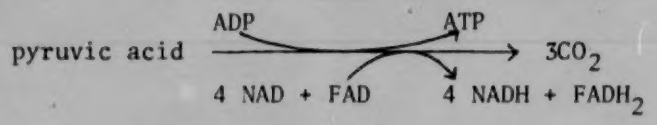
FIGURE 4: *Krebs cycle.*

In order to understand Figure 4, a new notation needs to be explained. Note the arrows between pyruvic acid and the 2-carbon compound. This notation is short for

$$\text{pyruvic acid} + \text{NAD} \longrightarrow CO_2 + \text{NADH} + \text{2-carbon compound}$$

This information is important because NADH is a compound with stored chemical energy that can be used to make ATP. In fact, most ATP is obtained from reactions involving NADH.

Although the Krebs cycle is complex, the main points can be summarized in a few sentences. First of all, pyruvic acid is degraded (broken down) to form a two-carbon compound which reacts with a four-carbon compound (oxalacetic acid) to form the six-carbon acid (citric acid). The citric acid is degraded in several steps finally leading to more oxalacetic acid. Thus the process may be continued as long as the two-carbon compound is being formed from pyruvic acid. In one turn of the Krebs cycle each molecule of pyruvic acid forms three molecules of CO_2 and an impressive number of high-energy compounds such as NADH and and $FADH_2$. Equation 6 summarizes the results.



$$\text{pyruvic acid} \xrightarrow[\text{4 NAD + FAD} \qquad \text{4 NADH} + FADH_2]{\text{ADP} \qquad \text{ATP}} 3CO_2 \qquad (6)$$

Keeping in mind that each glucose molecule produced two molecules of pyruvic acid, we can determine the combined results of glycolysis and the Krebs cycle by adding equations (4) and (6) to get (7).

$$\begin{array}{llr}
\text{glucose} + 2\ \text{ADP} + 2\ \text{NAD} & \rightarrow 2\ \text{pyruvic acid} + 2\ \text{ATP} + 2\ \text{NADH} & (4) \\
\underline{2\ \text{pyruvic acid} + 2\ \text{ADP} + 8\ \text{NAD} + 2\ \text{FAD}} & \underline{\rightarrow 6\ CO_2 + 2\ \text{ATP} + 8\ \text{NADH} + 2\ FADH_2} & (6) \\
\text{glucose} + 4\ \text{ADP} + 10\ \text{NAD} + 2\ \text{FAD} & \rightarrow 6\ CO_2 + 4\ \text{ATP} + 10\ \text{NADH} + 2\ FADH_2 & (7)
\end{array}$$

25-6 Oxidative Phosphorylation

Where does the oxygen come in?

Equation (7) looks somewhat like Equation (5). This is because the reactions of glycolysis and the Krebs cycle together explain most of what is accomplished in cell respiration. To go from Equation (7) to Equation (5), we have to explain where oxygen and water fit into the picture. This requires addition of one last process, oxidative phosphorylation. The long name is not as difficult as it sounds. The process involves two actions--oxidation, and the addition of phosphate groups to ADP to make ATP (phosphorylation).

In oxidative phosphorylation, NADH and $FADH_2$ react with O_2 to form NAD or FAD, and H_2O. Most important, energy is released in this reaction permitting ADP and phosphates to form ATP molecules. The details of this process are intricate, but the summation of glycolysis, the Krebs cycle and oxidative phosphorylation gives Equation (5). All of the useful energy formed is contained in ATP. A total of 36 ATP molecules are formed in cellular respiration from each molecule of glucose.

INFORMATION ON ACTIVITY 25:

TEACHING NOTES:

1. The purpose of this activity is to review some of the highlights of cell respiration as they relate to nutrition. The simulation game should help to make an abstract subject a little bit easier to relate to the human organism.

2. Anticipated time: two to four periods.

3. If you wish to shorten the activity, you should provide the student with most or all materials for the game and then eliminate Part I. For example, students could be provided with play money such as Monopoly money and given a color code to relate the play money to energy currency. Colored toothpicks could be used for energy currency. If desirable, Part II could be eliminated. However, this would result in the initial game being rather complicated. [Version I of the game (Part II) is deliberately much simpler than Version II of the game (Part III).]

4. The activity can be extended by allowing the students to try to improve the simulation (see Discussion Question 3). Also, another version of the game could be added in which the winner is the one who is first to complete the pathway an agreed number of times.

5. It would probably be a good idea to stress at the beginning of the game that the intent of the activity is NOT TO MEMORIZE ALL THE NAMES OR STRUCTURES ON THE BOARD.

6. Part II should not be started until students have read Section 25; Part III should not be started until students have read Section 26.

7. If your students tend to be argumentative, you might have each group elect a "judge" to settle disputes, or have each group agree to settle disputes by majority vote.

8. It is convenient to play in groups of four to six students per game board. They can gather around small tables if available or sit on the floor.

9. Some aspects of the simulation may be subtle and merit an announcement or a discussion.

a. The game calls for two turns of the Krebs cycle because each glucose molecule yields two pyruvic acid molecules and each of those molecules accounts for one turn of the Krebs cycle.

b. Part III suggests some of the varieties of pathways of metabolism that can occur.

c. The "Alternate Pathway" that starts near glucose phosphate is called the hexose monophosphate shunt. It provides a means for synthesis of ribose and other substances.

d. "Synthesis" cards show organelles of the cell that are important in synthesis of molecules. It takes energy to make these organelles so they cost 15 ATP's in the game.

e. When NADH is oxidized in a cell, 3 ATP's are obtained. The corresponding oxidation of $FADH_2$ yields only 2 ATP's.

10. It may be worthwhile to remind students that they may purchase "Synthesis" cards in Part III. This adds excitement to the game.

11. A more permanent-type game can be made by gluing the playing board to poster board or cardboard. The same is true for the various kinds of cards.

12. It would be a good idea to have some rubber bands on hand to assort the different kinds of currency and cards.

13. For oxygens, you may use buttons or checkers or poker chips or paper clips. For moving pieces, students could use coins or rings or small pieces of paper with their initials.

14. A sheet headed "Synthesis Cards" follows the Materials list. Prepare one copy of this sheet for every group. (The Materials list is based on 6 groups of 5 students each.) "Double bonus" on the mitochondrion card means "receive twice as many ATP's or NADH's, etc., as indicated on the playing board or in an 'Energy and Currency' card."

15. Following the sheet headed "Synthesis Cards," the playing board is given on 4 sheets. Each group will need one copy of each sheet.

16. Following the game board are 4 sheets of "Energy and Catalysis" cards. Each group will need one copy of each of these sheets.

17. Following the sheets of "Energy and Catalysis" cards, there is one sheet of "Enzyme" cards and one sheet headed "SELECT A PATHWAY." Each group will need one copy of each of these sheets.

18. For energy currency, students can make 21 bills from an $8\frac{1}{2}$ x 11 sheet. Thus each group will need 9 sheets. Typing paper can be used. Colored paper would be preferred so the different kinds of currency can be distinguished from each other. (Six different colors would be needed.) Crayons or felt pens could be used to distinguish the different kinds of currency.

MATERIALS: (for 6 set-ups)

- 6 game boards (Teaching Note 15)
- 6 rolls transparent tape
- 12-18 scissors
- 6 sheets "SYNTHESIS CARDS"
- 54 sheets, $8\frac{1}{2}$ x 11 inches (Teaching Note 18)
- crayons or felt pens (optional, see Teaching Note 18)
- 6-12 millimeter rulers
- 24 sheets "ENERGY AND CATALYSIS CARDS" (Teaching Note 16)
- 12 dice
- 6 moving pieces (Teaching Note 13)
- 500-600 "oxygens" (Teaching Note 13)
- 60 rubber bands

SYNTHESIS CARDS

RIBOSOME
(ENZYME SYNTHESIS)
LOSE NO TURNS
(two circuits of board)

RIBOSOME
(ENZYME SYNTHESIS)
LOSE NO TURNS
(two circuits of board)

RIBOSOME
(ENZYME SYNTHESIS)
LOSE NO TURNS
(two circuits of board)

MITOCHONDRION
(ATP SYNTHESIS)
DOUBLE BONUSES
(two circuits of board)

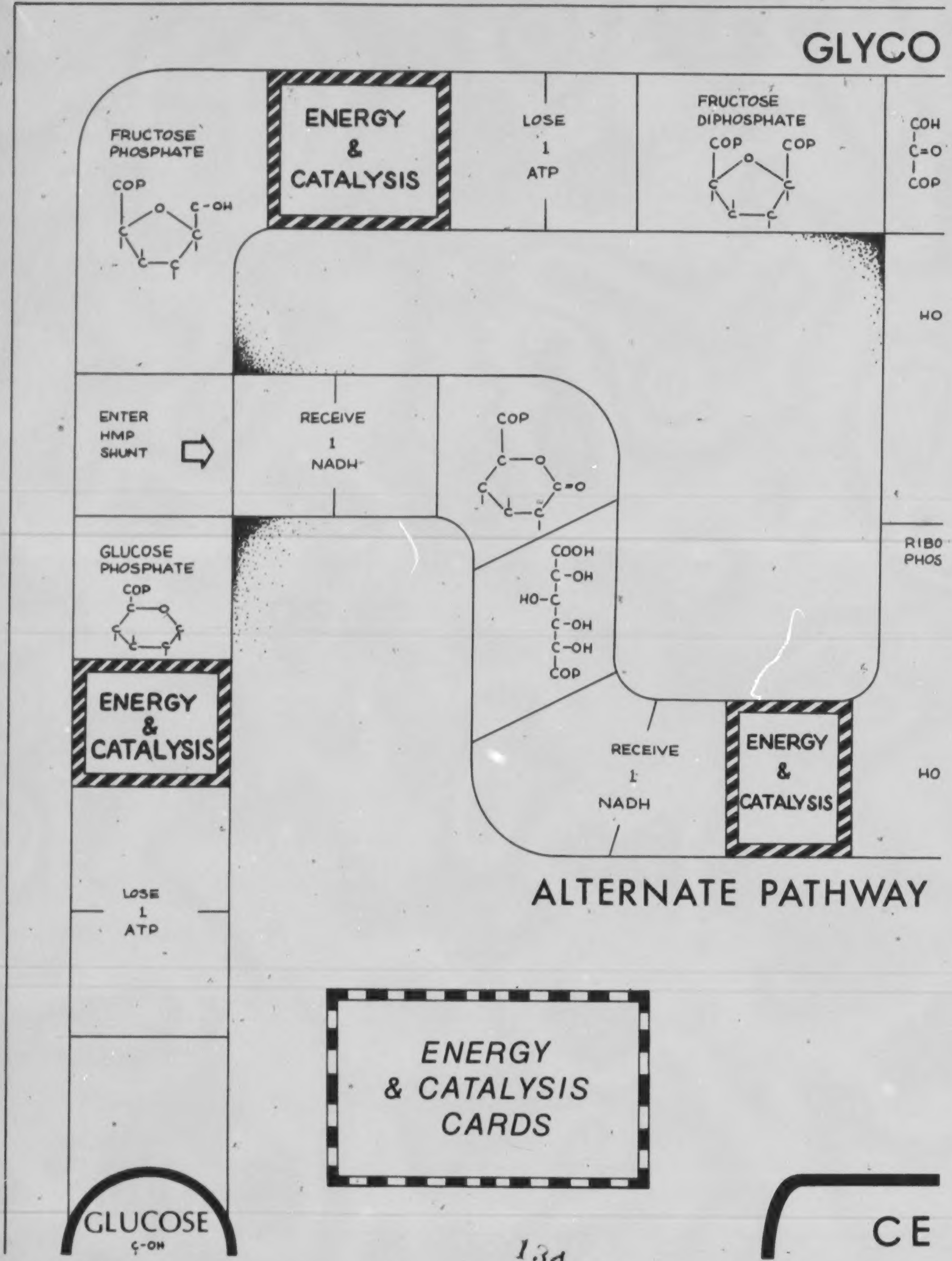
MITOCHONDRION
(ATP SYNTHESIS)
DOUBLE BONUSES
(two circuits of board)

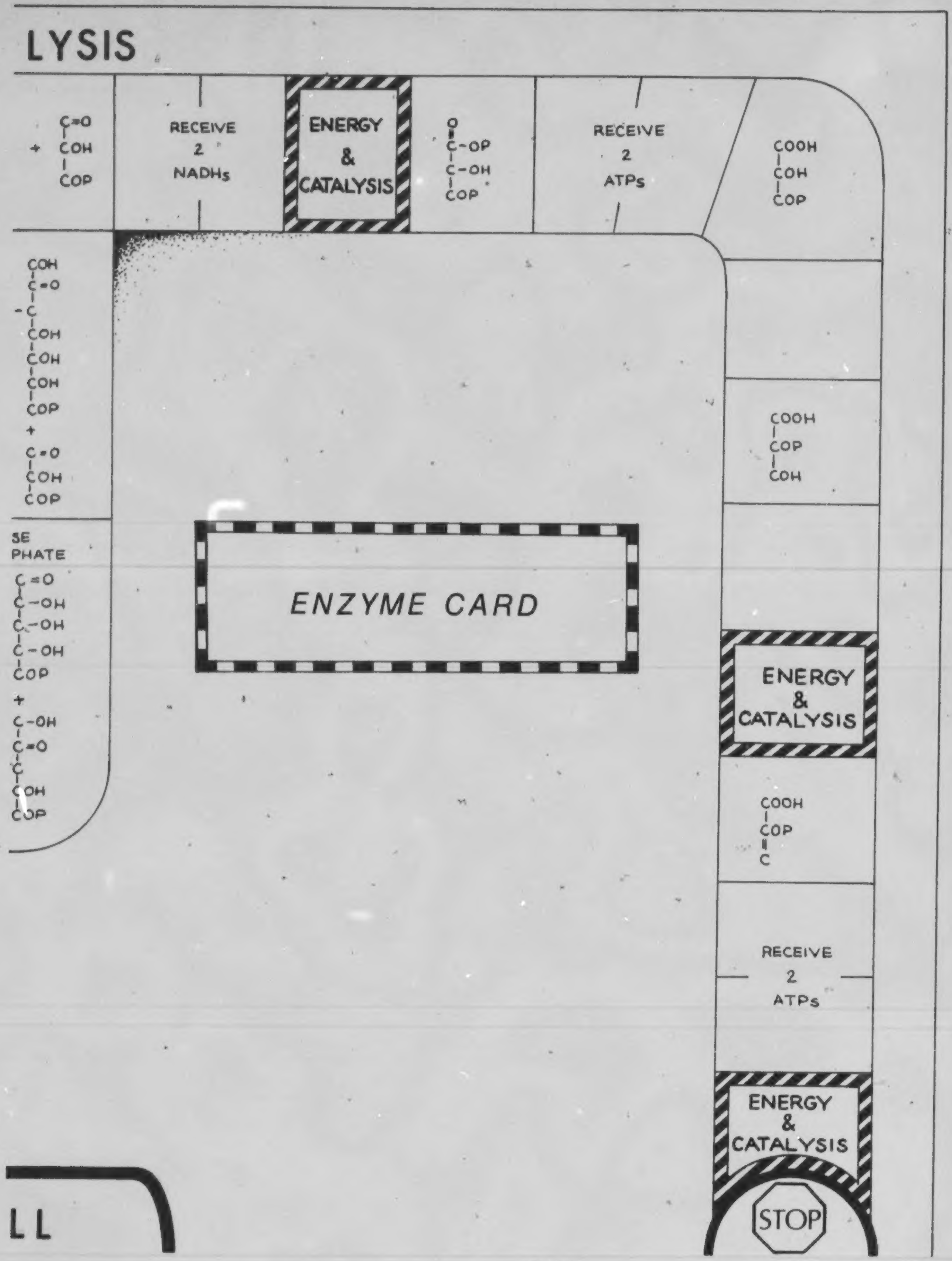
MITOCHONDRION
(ATP SYNTHESIS)
DOUBLE BONUSES
(two circuits of board)

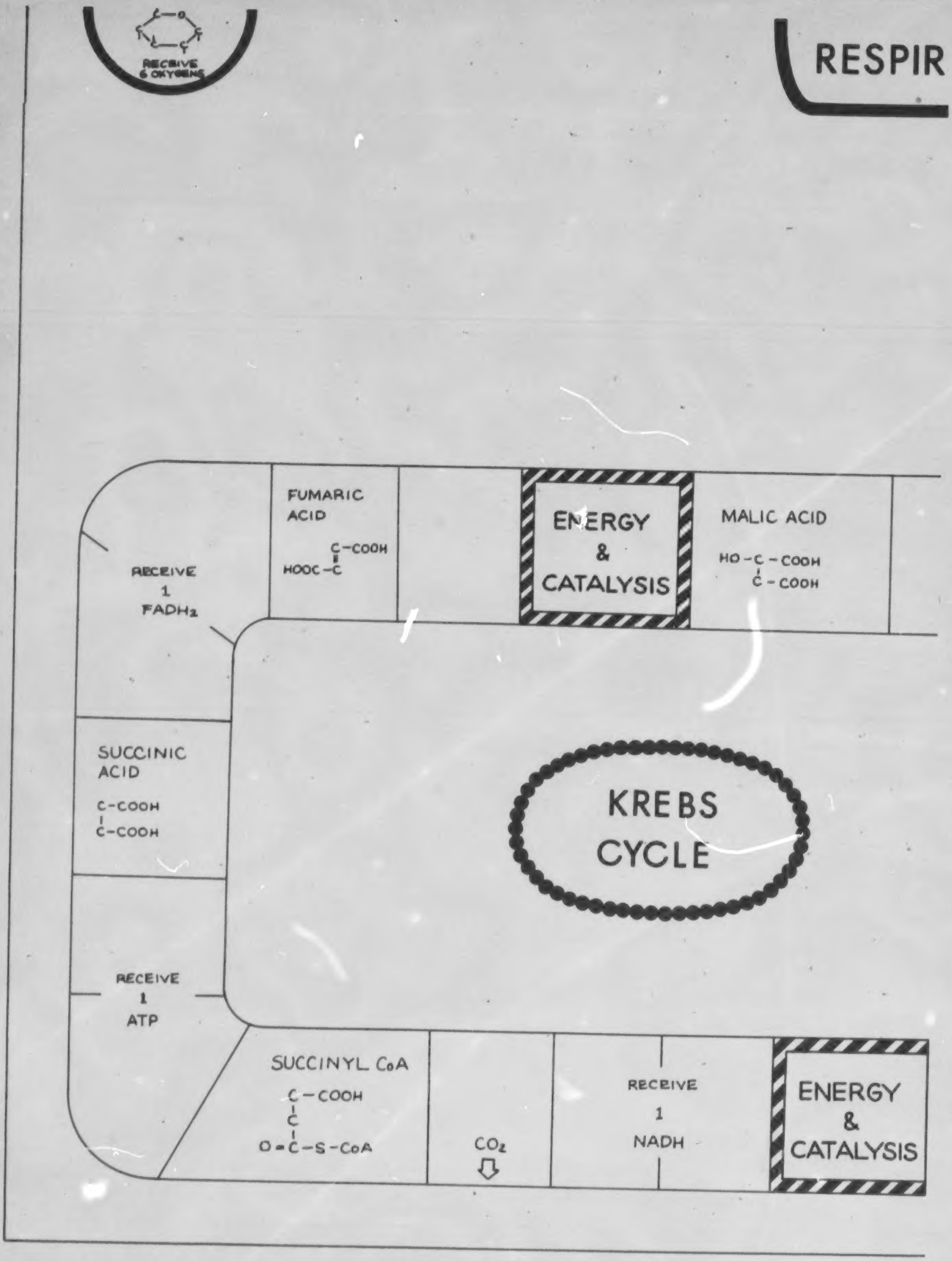
NUCLEUS
(GENE LOCATION)
4 EXTRA TURNS
(two circuits of board)

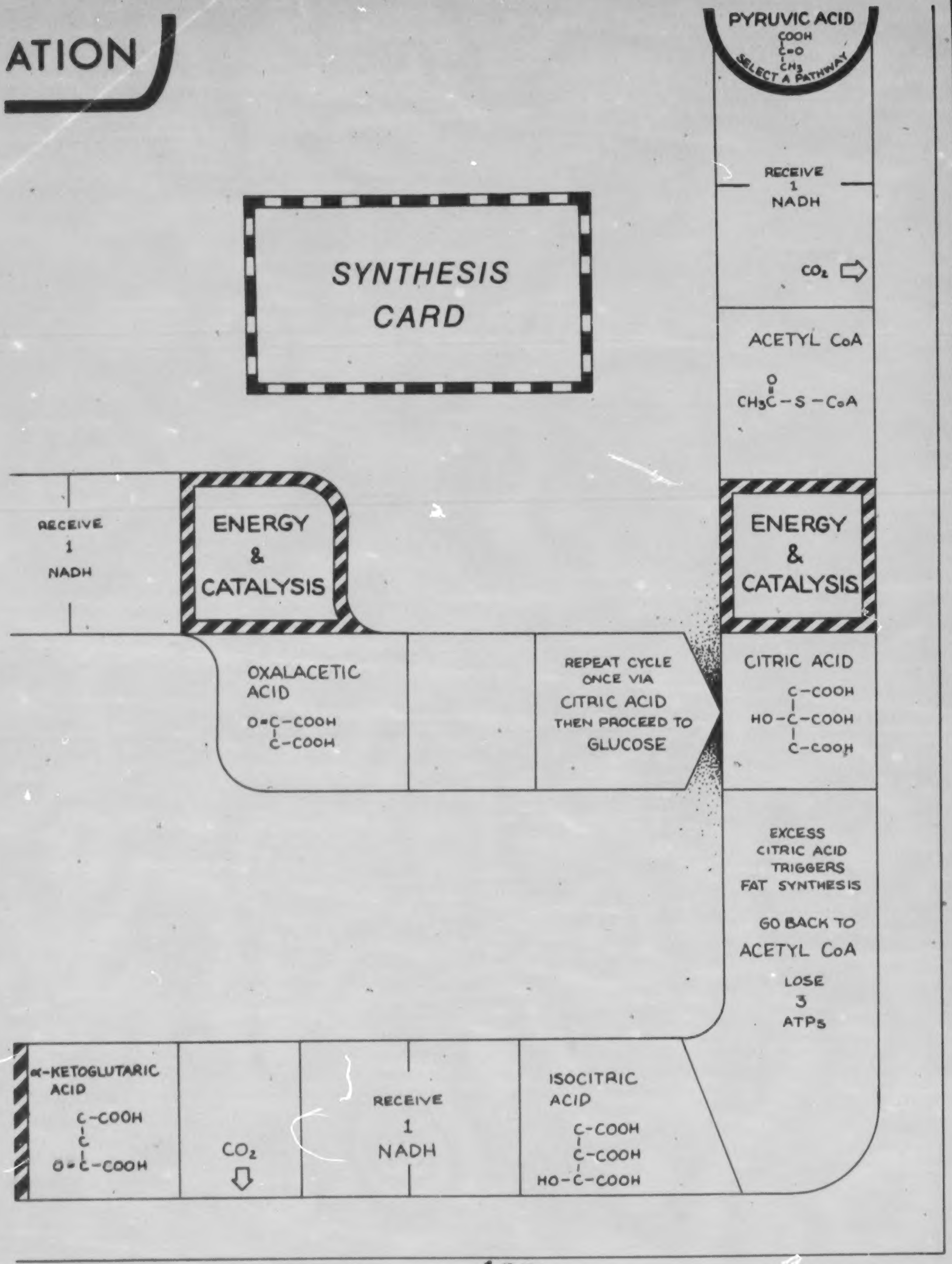
NUCLEUS
(GENE LOCATION)
4 EXTRA TURNS
(two circuits of board)

NUCLEUS
(GENE LOCATION)
4 EXTRA TURNS
(two circuits of board)


GLYCO
FRUCTOSE PHOSPHATE
COP
C-OH
O
C
ENERGY & CATALYSIS
LOSE 1 ATP
FRUCTOSE DIPHOSPHATE
COP
COP
COH
C=O
COP
HO
ENTER HMP SHUNT
RECEIVE 1 NADH
COP
C=O
GLUCOSE PHOSPHATE
COP
COOH
C-OH
HO-C
C-OH
C-OH
COP
RIBO PHOS
ENERGY & CATALYSIS
RECEIVE 1 NADH
ENERGY & CATALYSIS
HO
LOSE 1 ATP
ALTERNATE PATHWAY
ENERGY & CATALYSIS CARDS
GLUCOSE
C-OH
CE

LYSIS
+ C=O COH COP
RECEIVE 2 NADHs
ENERGY & CATALYSIS
O C-OP C-OH COP
RECEIVE 2 ATPs
COOH COH COP
COH C=O -C COH COH COH COP + C=O COH COP
SE PHATE
C=O C-OH C-OH C-OH COP + C-OH C=O C COH COP
COOH COP COH
ENZYME CARD
ENERGY & CATALYSIS
COOH COP C
RECEIVE 2 ATPs
ENERGY & CATALYSIS
STOP
LL


RECEIVE 6 OXYGENS
RESPIR
FUMARIC ACID
C-COOH
HOOC-C
ENERGY & CATALYSIS
MALIC ACID
HO-C-COOH
C-COOH
RECEIVE 1 FADH2
SUCCINIC ACID
C-COOH
C-COOH
KREBS CYCLE
RECEIVE 1 ATP
SUCCINYL CoA
C-COOH
C
O=C-S-CoA
CO2
RECEIVE 1 NADH
ENERGY & CATALYSIS


ATION
PYRUVIC ACID
COOH
C=O
CH3
SELECT A PATHWAY
RECEIVE 1 NADH
CO2
ACETYL CoA
O
CH3C – S – CoA
SYNTHESIS CARD
RECEIVE 1 NADH
ENERGY & CATALYSIS
ENERGY & CATALYSIS
OXALACETIC ACID
O=C–COOH
C–COOH
REPEAT CYCLE ONCE VIA CITRIC ACID THEN PROCEED TO GLUCOSE
CITRIC ACID
C–COOH
HO–C–COOH
C–COOH
EXCESS CITRIC ACID TRIGGERS FAT SYNTHESIS
GO BACK TO ACETYL CoA
LOSE 3 ATPs
α-KETOGLUTARIC ACID
C–COOH
C
O=C–COOH
CO2
RECEIVE 1 NADH
ISOCITRIC ACID
C–COOH
C–COOH
HO–C–COOH

ENERGY AND CATALYSIS CARDS

Good Work! The pepsinogen in your stomach has been changed to pepsin which is hydrolyzing proteins to amino acids and peptides. Some of the amino acids are being converted to pyruvic acid. Advance to pyruvic acid and "Select a Pathway."

An enzyme denatured by heat has just been replaced by freshly-made enzyme. Take an extra turn.

The coach made you drink some honey before the race. Honey is rich in glucose and fructose. Advance to glucose or fructose phosphate. Receive from metabolic pool 6 oxygen molecules.

A molecule of NADH is oxidized. In this exothermic reaction, 3 ATP molecules form. Receive same from metabolic pool.

You just lifted up your arm and contracted muscles when you shot the dice. This requires energy and will cost you 4 ATP's. Pay metabolic pool.

You have just finished a chopped-liver sandwich. Since liver is a good source of essential amino acids, you can now make more enzymes (proteins). Take two extra turns.

You stopped smoking and fewer of your hemoglobin molecules are tied up with carbon monoxide. Now you can transport more oxygen to your cells. Receive 6 oxygen molecules.

You have just eaten a slice of whole-wheat bread, a good source of thiamin. Thiamin helps convert pyruvic acid to acetylcoenzyme A. Advance to acetylcoenzyme A and take another turn.

Bad news. Your drinking water is contaminated by mercury. This element inhibits some enzymes. If you have an enzyme card, return it to the metabolic pool. Otherwise, lose a turn.

You weren't supposed to swallow the fluoridated toothpaste. Fluoride inhibits certain metabolic steps early in glycolysis. Go back to glucose and lose one turn.

ENERGY AND CATALYSIS CARDS

You have just had a bean and lettuce sandwich on whole-wheat bread. These are good sources of magnesium. Magnesium prevents the inhibition of enzymes by fluoride. For the rest of the game, you may ignore all cards on fluoride inhibition.

Somebody slipped some cyanide into the celery soup. This poison interferes with Krebs cycle metabolism. All players in the Krebs cycle lose one turn.

Emergency. Mucus is being produced in response to an allergy and this takes energy. Return 3 ATP's to the metabolic pool.

Your diet is low in phosphorus, an element required for production of ATP. Your nutritional deficiency will cost you 2 ATP's.

A gene just signalled a liver cell to make an enzyme. Take 1 enzyme card.

A gene in one of your skin cells just gave the word to make an enzyme. Take 1 enzyme card.

A gene in one of your pancreatic cells just gave the word to make an enzyme. Take 1 enzyme card.

A gene in one of your muscle cells just gave the word to make an enzyme. Take 1 enzyme card.

A gene in a white blood cell just gave the word to make an enzyme. Take 1 enzyme card.

A gene in one of your stomach cells just gave the word to make an enzyme. Take 1 enzyme card.

ENERGY AND CATALYSIS CARDS

A gene in one of your bone cells just gave the word to make an enzyme. Take 1 enzyme card.

Your mitochondria (cell organelles) are in great shape and, as a result, Krebs cycle metabolism is progressing rapidly. If you are in the Krebs cycle, take an extra turn.

ATTENTION. Ribose is urgently needed to make a substance that carries genetic messages. Go back to glucose phosphate. On your next turn, proceed through the "Alternate Pathway."

Your salivary glands have just secreted amylase (in saliva), and the starch in a pizza you're eating is being digested. Advance to glucose and receive 6 oxygen molecules.

Ahoy! The food is coming down the esophagus with peristaltic waves. Energy will soon be released. Receive 5 ATP's.

The pyloric valve has just opened and chyme is passing from the stomach to the duodenum. Take an extra turn.

You got an A in a Biomedical Science test, got excited and started to hyperventilate. The blood pH has changed and the pH is now unfavorable to most enzymes. Lose one turn while you breathe into a paper bag.

Your gallbladder has just released a pile of bile causing emulsification of fats in the duodenum. This will make possible digestion and absorption of fats. Receive 5 ATP's.

You just absorbed some sugar molecules in the villi of the small intestines. The sugars will soon be available for energy. Receive 5 ATP's.

Good News. You have recovered from hepatitis and your liver is now doing a better job of cell respiration. Receive 5 ATP's.

ENERGY AND CATALYSIS CARDS

You have just taken up jogging and are releasing more energy than you are consuming from foods. That will cost you 3 ATP's.

You have a slight case of anemia. Your serum hemoglobin concentration is below normal. That will cost you 4 oxygen molecules.

"Lactose Intolerance" is intolerable. Because of your inability to digest lactose, you are low in glucose. Go back to glucose and lose a turn while you switch to a low-lactose diet.

The diagnosis is diabetes. Your pancreas is not making enough insulin. As a result, glucose molecules are not getting into your cells. That will cost you 4 ATP's.

Your thyroid gland just secreted some thyroxin and your BMR has increased. Take two extra turns.

Something is wrong with your homeostatic controls. Lose one turn, then take two turns in succession.

Your BMR shows an increased metabolic rate. Receive 5 ATP's.

Your diet is rich in meat and whole grain products so you are obtaining lots of niacin. Niacin is the raw material for production of NADH. Receive 3 NADH's.

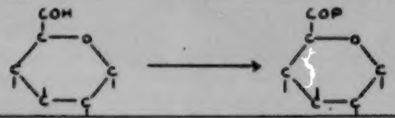
Some liver glycogen has just hydrolyzed to glucose. This will soon provide lots of energy. Receive 5 ATP's.

You have just had a pot roast and peanut butter sandwich on whole-wheat bread. These are good sources of pantothenic acid. This vitamin is needed for production of acetyl CoA. Advance to this molecule and take another turn.

ENZYME CARDS

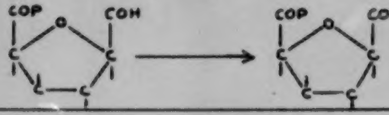
ENZYME

GLUCOSE → GLUCOSE PHOSPHATE



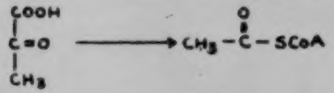
ENZYME

FRUCTOSE PHOSPHATE → FRUCTOSE DIPHOSPHATE



ENZYME

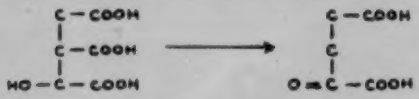
PYRUVIC ACID → ACETYL CoA



$$\begin{array}{c}COOH\\ |\\ C{=}O\\ |\\ CH_3\end{array} \longrightarrow CH_3-\overset{O}{\overset{\|}{C}}-SCoA$$

ENZYME

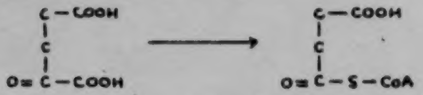
ISOCITRIC ACID → α-KETOGLUTARIC ACID



$$\begin{array}{r}C-COOH\\ |\\ C-COOH\\ |\\ HO-C-COOH\end{array} \longrightarrow \begin{array}{r}C-COOH\\ |\\ C\\ |\\ O{=}C-COOH\end{array}$$

ENZYME

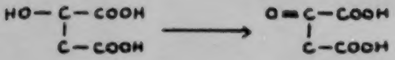
α-KETOGLUTARIC ACID → SUCCINYL CoA



$$\begin{array}{r}C-COOH\\ |\\ C\\ |\\ O{=}C-COOH\end{array} \longrightarrow \begin{array}{r}C-COOH\\ |\\ C\\ |\\ O{=}C-S-CoA\end{array}$$

ENZYME

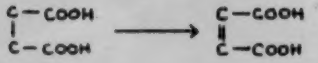
MALIC ACID → OXALACETIC ACID



$$\begin{array}{r}HO-C-COOH\\ |\\ C-COOH\end{array} \longrightarrow \begin{array}{r}O{=}C-COOH\\ |\\ C-COOH\end{array}$$

ENZYME

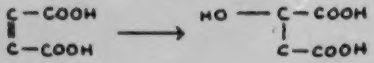
SUCCINIC ACID — FUMARIC ACID



$$\begin{array}{r}C-COOH\\ |\\ C-COOH\end{array} \longrightarrow \begin{array}{r}C-COOH\\ \|\\ C-COOH\end{array}$$

ENZYME

FUMARIC ACID → MALIC ACID



$$\begin{array}{r}C-COOH\\ \|\\ C-COOH\end{array} \longrightarrow \begin{array}{r}HO-C-COOH\\ |\\ C-COOH\end{array}$$

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SELECT A PATHWAY

Dice Total	
2 or 6 or 11	Normal metabolism. On your next turn, proceed through the Krebs cycle. Remember to make two loops.
3 or 7 or 10	You are on a well-planned reducing diet. Fats are being broken down and are releasing energy for synthesis of ATP. Receive double bonuses twice around the Krebs cycle.
4 or 9 or 12	You are suffering from diabetes and are having trouble getting glucose into your cells. Use only one die twice around the Krebs cycle.
5 or 8	Because of a temporary shortage of ribose, go back to glucose phosphate. On your next turn,, go through the alternate pathway.

ANTICIPATED RESULTS:

As a result of the games, students should have a better conception of the material covered in Sections 25 and 26 and an idea of some of the ways that nutrition and medicine are related to cell respiration.

ANSWERS TO DISCUSSION QUESTIONS:

1. The second version because it includes the relationship of many things that may happen in the cell or in a person that affect cell respiration.

2. Answers will vary. There are many ways that the simulation differs from real life. One interesting point to consider is that life is not as "chancy" as the game suggests.

3. Answers will vary. (You may wish to discuss "simulations" with your social science colleague since this technique is used more commonly in Biomedical Social Science than in this course.)

LESSON 26: FACTORS RELATED TO CELL RESPIRATION

RATIONALE:

ST-25 considered the breakdown of glucose and the related generation of ATP. ST-26 shows how other nutrients, namely fats and proteins, are related to cell respiration. In addition, the roles of genes, enzymes, vitamins and cell structure in cell respiration are discussed. Part III of the simulated cell respiration game (Activity 25) includes a review of ST-26.

OBJECTIVES:

The student will:

- list at least two nutrients in addition to glucose that are metabolically linked to cell respiration.
- state why enzymes are necessary for cell respiration.
- state how a gene controls a metabolic step.
- state that a vitamin may function by aiding an enzyme in the catalysis of a metabolic step.
- define organelle.

SUGGESTIONS:

1. Part III of Activity 25 (the simulation game) is dependent upon the concepts covered in ST-26 and should follow a discussion of this material. The simulation game may stimulate some questions on cell respiration. It might be a good idea to leave some time for a discussion after the students complete the game.

2. ST-26 introduces subcellular anatomy and electron microscopy very briefly. This might be a good opportunity to develop these subjects in more depth. A discussion of mitochondria and cell respiration would be especially worthwhile. For background material refer to a college cell physiology text such as B. Pansky's, Dynamic Anatomy and Physiology, Macmillan Publishing Co., N.Y., 1975, or W.V. Brown and E.M. Bertke's, Textbook of Cytology, Second ed., C.V. Mosby Co., St. Louis, 1974.

3. This lesson affords an opportunity to review the roles of certain hormones. You might mention, for example, that insulin and thyroxin increase the rate of cell respiration.

LESSON 27: CHEMICAL EQUILIBRIUM

RATIONALE:

In ST-27, equilibria are considered because they are important biologically and because they are basic to both chemistry and physics. A treatment of reversible reactions and equilibria in ST-27 leads to a consideration of the role of ATP in metabolism in ST-28. The concept of equilibrium will be useful later in the Biomedical Science curriculum and will be related to quadratic equations in the Biomedical Mathematics course. LA-27 considers a reversible reaction and how equilibrium can be shifted. The shifting of an equilibrium position is the subject of ST-28.

OBJECTIVES:

The student will:

- define and give at least two examples of chemical equilibria.
- distinguish between a "static" and a "dynamic" equilibrium.
- define saturated solution and describe what is happening at equilibrium.

- list at least one example of a chemical equilibrium in which there are mostly products.
- list at least one example of a chemical equilibrium in which there are mostly reactants.

SEQUENCE: ST-27; LA-27 (or reverse)

SUGGESTIONS:

1. A simple analogy that may be useful in explaining the concept of a dynamic equilibrium is player substitutions in a football game. Every time a player is added, another is removed from the playing field so that the total number of players on each side is constant.

2. The subject of equilibrium may be extended in several directions as indicated in the supplement to the Student Text located after the suggestions. This material was not included in ST-27 because it digresses from the energy-metabolism theme of Sections 22 through 28, yet it may be of value to you in clarifying the concept of equilibrium. You may wish to make copies of the supplement for your class.

3. In Section 27-2, there is a possible semantical problem that may bother a few students. That is, when we speak about "more product molecules than reactant molecules," we are speaking about proportions of products to reactants rather than the number of different product and reactant molecules. This may be made clear with an example. Suppose we have an equilibrium in which

$$A + B \rightleftharpoons C + 2\,D$$

If we say that at equilibrium, there are more products than reactants, we do not mean that there are 3 molecules of product (1 C + 2 D) to every 2 molecules of reactant (1 A + 1 B). We simply mean that the total number of C + D molecules is greater than the total number of A + B molecules.

SUPPLEMENT TO SECTION 27:

27-3 Other Kinds of Equilibria

What are some other biologically important examples of equilibria?

The equilibrium concept is a very useful one not only because it applies to nutrition and chemical reactions and to solubility problems, but also because it helps to explain biologically important phenomena. Recall, for example, the activity on diffusion of food color in Unit I. The color gradually spread from one small area eventually filling the entire vessel. When the color was evenly spread, what was the state of the food-coloring molecules? One conceivable answer to this question is that the molecules had stopped moving. But this is not reasonable because molecules are always moving (except at absolute zero). The correct answer is that the molecules were moving in all directions. This kind of disorganized movement in all directions is called random motion and exemplifies a dynamic equilibrium.

Another example of an equilibrium relates to the level of oxygen in the blood. As oxygen molecules are used up in respiration, other oxygen molecules are transported from the blood to body cells to replace them. So the concentration of oxygen in the blood normally remains about the same.

You may recall that your old friend Tom ran into several problems with oxygen in Unit I. In one case, when he climbed Mt. Whitney, he was unable to breathe in enough oxygen to maintain his blood oxygen level. This was because of the reduced partial pressure of oxygen at high altitudes. At a reduced partial pressure, less oxygen would bind to hemoglobin. As a result, his equilibrium was disturbed and this led to dramatic physiological effects. (For a review of the effect of high altitude on body oxygen level, you may refer to Unit I, Sections 15, 16 and 31.)

The concept of equilibrium provides another way to look at homeostasis. Homeostatic devices invariably entail some kind of equilibrium. For example, the normal body maintains fairly constant levels of O_2, CO_2, electrolytes, glucose and many other substances. Values of these substances outside of the normal ranges indicate that one or more body equilibria have been disturbed. Such clinical results are of great medical importance. They may be the first clue to a serious illness.

The concept of equilibrium may also be applied to human populations. Many scientists are concerned about the continually increasing world population. They fear that the available food resources cannot keep up with the increasing number of mouths to feed. Some people, including a number of scientists, have recommended that the total world population be kept at a constant level. A stable population would result if there were an equilibrium in which the number of births equaled the number of deaths. Can you explain why this would be a "dynamic" rather than a "static" equilibrium?

INFORMATION ON LABORATORY ACTIVITY 27:

TEACHING NOTES:

1. The purpose of this activity is to reinforce ST-27 by demonstrating that the concentration of products will change if the concentrations of reactants are changed. In addition, data taken during the activity are used to calculate the equilibrium constant, K_{eq}, which remains the same despite the changes in concentrations of participants in the reaction.

2. Anticipated time: two periods.

3. The activity may be stopped any time after Part I, Step 7, and resumed later. The procedure assumes that Parts I and II occur on different days.

4. Part II may be omitted if you wish to condense the activity. A calibration curve is provided on p. 136 in case this activity is not performed.

5. The calibration curve in Part II is made with potassium dichromate in water. However, in Part I, the dichromate forms in a chromate solution rather than in water. Nevertheless, the effect on absorbance is slight, and it is easier to prepare the solutions in this manner. Note that the curve is non-linear at low concentrations of dichromate. For this reason, the students are instructed to depart from the usual procedure of drawing a "best" straight line.

6. Part I calls for pH measurements. These are needed for Part III. These measurements should be accurate to ± 0.2 pH units if possible. This is why narrow-range pH paper (pH 6.0 to 8.0) is called for.

7. The BIP pH probe may be used in addition to, or instead of, pH paper. If there is only one probe per class, each group can be assigned to measure the pH in only one or two of its cuvets, so that there will be enough time for every group to use the probe. The class pH data can then be shared. If the pH probe is used, more solution will be needed than described in Part I, and the procedure will have to be modified very slightly.

Note: It is important to rinse the pH probe thoroughly before each measurement. Do this by moving it around in a beaker of distilled water for 10 seconds or more. This step removes the solution that remains on the probe, which will affect the reading if it is not rinsed off. Use about 100 ml of distilled water for a rinse bath and change it after every 15 to 20 rinses.

8. Part I, Step 8, asks students to suggest a way to reverse the reaction and then to try it out. The answer is to add a base. This may not be obvious and may require a class discussion. There are two ways to explain how this reverses the reaction. The reaction is

$$2\ CrO_4^{-2} + 2\ H^+ \rightleftharpoons Cr_2O_7^{-2} + H_2O$$

If a base is added, it reacts with the H^+ ions to form water. This removes H^+ ions, so that the reaction shifts to the left. Another way to explain the effect is that the base reacts with dichromate by the following reaction.

$$Cr_2O_7^{-2} + 2\ OH^- \rightleftharpoons 2\ CrO_4^{-2} + H_2O$$

9. In Part III students calculate the equilibrium constant, K_{eq}, for the chromate-acid reaction in three cuvets. The calculations involve some time-consuming arithmetic. If three prove to be too many, one may be assigned as homework or group work. You may wish to review multiplication and division in scientific notation.

The instructions call for rounding to one digit after each calculation. This simplifies calculations considerably. However, if you desire more accuracy, numbers may be rounded to two digits.

10. In the formula for K_{eq}, the concentration of water is considered 1 "by convention." This is because in the solutions that concern us the concentration of water is always much larger than the concentration of the solutes, and varies very little. Hence the concentration of water is considered constant and is ignored in the calculation of K_{eq}. "Ignoring $[H_2O]$ in such calculations is equivalent to treating $[H_2O]$ as 1.

11. The reason K_{eq} is calculated for only three of the five cuvets is that the two cuvets containing the highest acid concentrations would not yield accurate values for K_{eq}. There are several reasons for this. First, the pH can be measured accurately in only the three cuvets with intermediate acid concentrations (because these lie in the pH range of the 6.0 to 8.0 paper).

Second, at high acid concentrations, new products may appear in the test tube which are not taken into account.

Third, high acid concentrations produce near-maximum dichromate concentrations. This introduces a large uncertainty in the calculated chromate concentrations, as shown by the following example. Suppose that for cuvet #4,

$$\left[Cr_2O_7^{-2}\right] = .039 \pm .0005$$

as determined from the calibration curve. Next, we use this value to find the chromate concentration.

$$\left[CrO_4^{-}\right] = .080 - 2\left[Cr_2O_7^{-2}\right]$$

$$\left[CrO_4^{-}\right] = .080 - 2(.039 \pm .0005)$$

Next we rewrite the last term

$$2(.039 \pm .0005) = (.039 \pm .005) + (.039 \pm .0005)$$

$$= .078 \pm .001$$

Therefore,

$$\left[CrO_4^{-}\right] = .080 - (.078 \pm .001)$$

In other words,

$$\left[CrO_4^{-}\right] = .080 \pm 0 - (.078 \pm .001)$$

$$= .002 \pm .001$$

Notice that $\left[CrO_4^{-}\right]$ has a relative uncertainty of 50%. Since the calculation of K_{eq} requires multiplication and division of the concentrations of $\left[CrO_4^{-}\right]$, $[H^+]$ and $\left[Cr_2O_7^{-2}\right]$, the relative uncertainties of all the concentrations are added. This means that the relative uncertainty of K_{eq} would be 50% in this case.

12. Options:

a. Add 1 ml of 0.1 M $Ba(NO_3)_2$ (or 0.1 M $BaCl_2$) to each of the potassium chromate acid solutions made in Part I. In the tubes with potassium chromate a yellow precipitate will form.

$$Ba^{+2} + CrO_4^{-2} \rightarrow BaCrO_4$$

The more potassium chromate, the more precipitate will form. Those cuvets in which most of the chromate was converted to dichromate will show little or no precipitation when barium is added.

b. Make increasing concentrations of potassium chromate in water and measure the pH. Relate the change in pH to the equation for the reaction of chromate with H^+ ions. Do the same with potassium dichromate.

MATERIALS: (for 10 set-ups)

- 14.57 g potassium chromate (K_2CrO_4)
- 16.7 ml conc. HCl
- 8 g sodium hydroxide (NaOH)
- 11.03 g potassium dichromate ($K_2Cr_2O_7$)
- 5.23 g barium nitrate [$Ba(NO_3)_2$], (optional) or 4.89 g barium chloride ($BaCl_2 \cdot 2H_2O$) (optional)
- 20 beakers, 150-ml
- 10 beakers, 50-ml
- 10 pipets, 10-ml
- 120 cuvets, 16 x 125 mm, Pyrex
- 10 test-tube racks
- 10 BIP colorimeters
- 1 roll pH test paper, range 6.0-8.0
- 1 roll pH test paper, range 1-6 or 0-11
- 10 glass-marking pencils
- graph paper, 60 sheets

PREPARATION OF REAGENTS:

0.1 M Potassium chromate, 750 ml: 14.57 ± .01 g potassium chromate + sufficient water to make 750 ml.

1 M Hydrochloric acid, 200 ml: Add 16.7 ± .2 ml conc. HCl to sufficient water to make 200 ml.

1 M Sodium hydroxide solution, 200 ml: 8 ± .5 g NaOH + sufficient water to make 200 ml.

0.05 M Potassium dichromate, 750 ml: 11.03 ± .01 g potassium dichromate + sufficient water to make 750 ml.

0.1 M Barium nitrate, 200 ml (optional): 5.23 ± .01 g $Ba(NO_3)_2$ + sufficient water to make 200 ml.

0.1 M Barium chloride, 200 ml (optional): 4.89 ± .01 g $BaCl_2 \cdot 2H_2O$ + sufficient water to make 200 ml (or use 4.17 ± .01 anhydrous $BaCl_2$).

ANTICIPATED RESULTS:

PART I:

Colorimeter readings and their corresponding absorbances, which were observed in our lab, are given in the table on the following page. pH is also shown, as measured with pHydrion paper, range 6.0-8.0 (whenever possible) and range 1-6.

Cuvet	Molarity of HCl added	% T	Absorbance	pH
0	0	100.0	.000	7.4
1	0.1	82.0	.085	6.8
2	0.2	73.0	.135	6.6
3	0.3	68.0	.165	6.4
4	0.4	62.5	.205	3.5
5	0.5	62.5	.205	1

PART II:

Colorimeter readings and their corresponding absorbances were observed to be the following in our lab.

Tube	Molarity of $K_2Cr_2O_7$ added	% T	Absorbance
0	0	100	.000
1	.005	88	.055
2	.01	80	.095
3	.02	72	.145
4	.03	66	.180
5	.04	61	.215
6	.05	57	.245

The calibration curve drawn from these data is provided (Graph 1).

The calibration curve provided yields the following concentrations of dichromate from the absorbances in Part I:

Tube	Absorbance	Dichromate concentration (molarity)
0	.000	.00
1	.085	.0085
2	.135	.0175
3	.165	.026
4	.205	.0375
5	.205	.0375

Step 8. Graph 2, on the following page, shows the concentration of dichromate as a function of acid concentration.

PART III:

1. The sample data above give the following results.

a. $[Cr_2O_7^{-2}]$ was determined in Part II, Step 7. Values are listed there.

b. $[CrO_4^{-2}] = .08\ \frac{\text{mole}}{\text{liter}} - 2[Cr_2O_7^{-2}]$. This yields the following values, using values for $[CrO_4^{-2}]$ rounded to one digit.

Tube	$[Cr_2O_7^{-2}]$	$[CrO_4^{-2}]$
1	.009	.06
2	.02	.04
3	.03	.02

c. $[H^+]$ = -antilog pH. The pH values measured in Part I above yield the following sample values for H^+ (from the table).

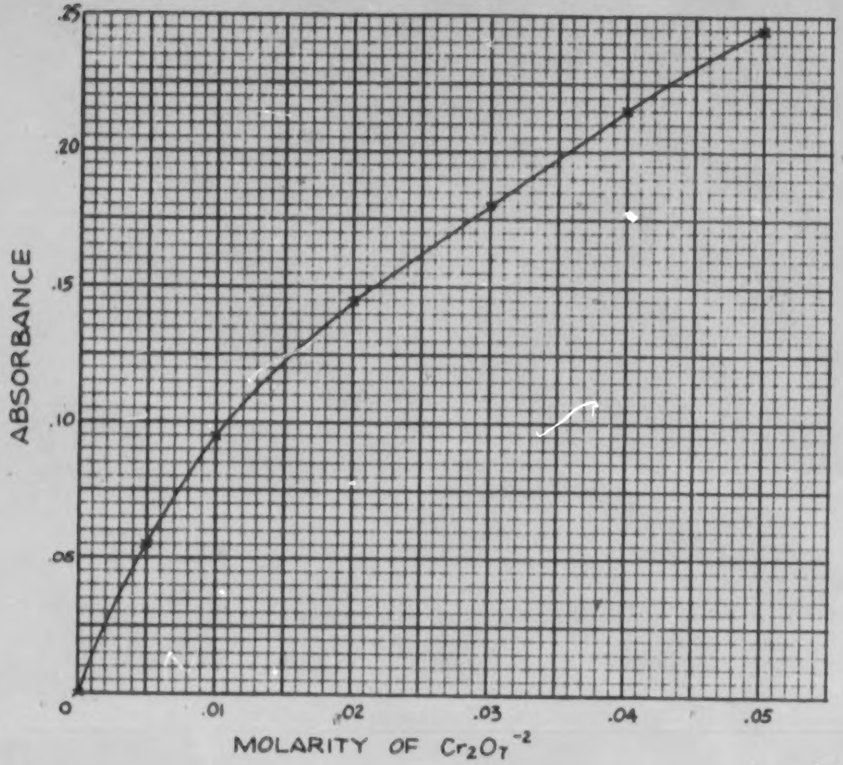
Tube	pH	$[H^+]$
1	6.8	2×10^{-7}
2	6.6	3×10^{-7}
3	6.4	4×10^{-7}

2. Squares are:

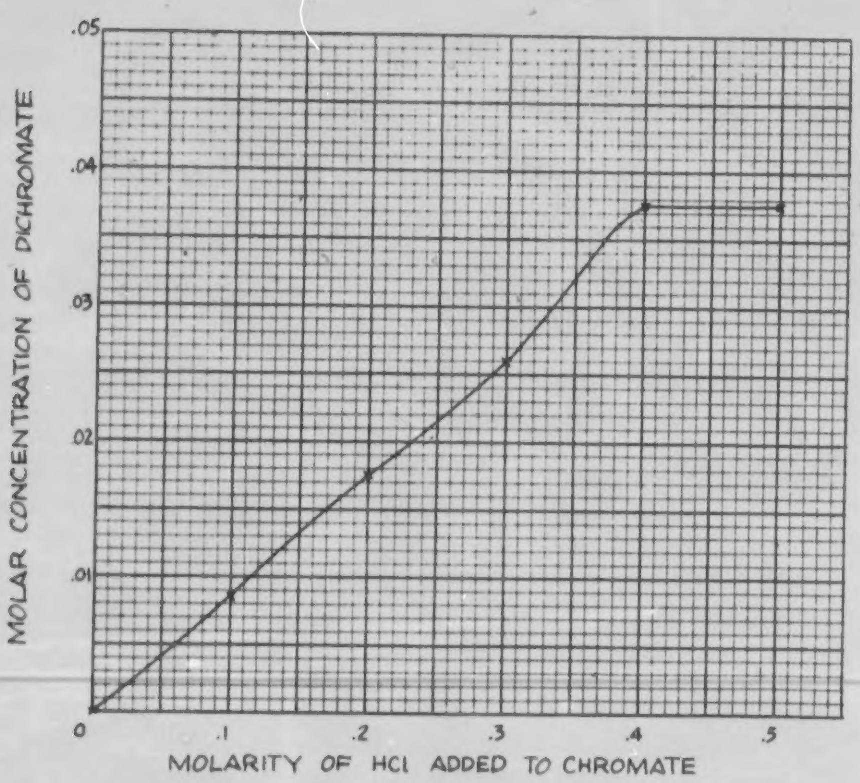
Tube	$[CrO_4^{-2}]$	$[CrO_4^{-2}]^2$
1	.06	4×10^{-3}
2	.04	2×10^{-3}
3	.02	4×10^{-4}

Tube	$[H^+]$	$[H^+]^2$
1	2×10^{-7}	4×10^{-14}
2	3×10^{-7}	9×10^{-14}
3	4×10^{-7}	2×10^{-13}

GRAPH 1
(CALIBRATION CURVE)



GRAPH 2



3. $K_{eq} = \frac{[Cr_2O_7^{-2}][H_2O]}{[CrO_4^{-2}]^2[H^+]^2} = \frac{[Cr_2O_7^{-2}]}{[CrO_4^{-2}]^2[H^+]^2}$

Cuvet	K_{eq}
1	$\frac{.009}{(4 \times 10^{-3})(4 \times 10^{-14})} \approx .6 \times 10^{14}$
2	$\frac{.02}{(2 \times 10^{-3})(9 \times 10^{-14})} \approx 1 \times 10^{14}$
3	$\frac{.03}{(4 \times 10^{-4})(2 \times 10^{-13})} \approx 4 \times 10^{14}$

ANSWERS TO DISCUSSION QUESTIONS:

1. Dichromate ions--orange color; chromate ions--yellow color.

2. More.

3. Left.

4. Bases, such as sodium hydroxide, decrease the hydrogen ion concentration. This causes dichromate to form chromate.

5. Any acid, such as acetic, nitric, sulfuric, etc.

6. As the concentrations of HCl approached 0.5 M, not much addition dichromate formed because the reaction was nearly complete.

7. Potassium chormate uses up the H^+ ions in water when it reacts with them to form dichromate. Removal of H^+ increases the proportion of OH^- and thus raises the pH.

8. See Teaching Note 5. Since the standard was made with dichromate in water, it absorbs less light than the dichromate which forms in a chromate solution.

9. Values for K_{eq} will probably be found to differ. This is due to the inaccuracy of the measurements, including pH and % T. The standard curve contains a small inaccuracy as well (see Question 8, above). Finally, the theory has inaccuracies as well. Molarities are actually only an approximate measure of the active ions in a solution. To calculate K_{eq}, molarity must be multiplied by a constant called the activity coefficient, which takes complex physical chemical considerations into account.

10. Since K_{eq} is so large, there will be more products than reactants at equilibrium. The reaction is exothermic.

LESSON 28: (A) SHIFTING THE POSITION OF AN EQUILIBRIUM

(B) THE EQUILIBRIUM CONSTANT

RATIONALE:

In some reactions that occur in the body, such as the formation of peptides from amino acids, the equilibrium would be expected to favor the reactants. In other words, if we dissolved amino acids together in a beaker of water and allowed enough time for equilibrium to be reached, very little peptide would be present. Yet this same reaction occurs in the cell and much product forms (otherwise we could not survive). The mechanism by which the body shifts "unfavorable" equilibria is considered in ST-28. These factors include energy, ATP and the concentrations of the participants in a reaction. In addition ST-28 considers how the position of an equilibrium can be described numerically with an equilibrium constant. The laboratory activity provides an opportunity to determine the equilibrium constant for a reaction from data collected in LA-27.

OBJECTIVES:

The student will:

- state the relationship between heat of reaction and the position of an equilibrium.
- give an example of how ATP shifts the position of a chemical equilibrium.
- state and give at least one example of Le Chatelier's principle.
- describe at least two ways in which a product can be removed from a reaction.
- calculate the equilibrium constant for a simple reaction, given the balanced equation.

SEQUENCE: ST-28; LA-27

SUGGESTIONS:

1. Note that Part III of LA-27 is based to a degree on ST-28 so this material should be covered in class prior to that activity.

2. Another example of shifting an equilibrium position involves the formation of ATP. The equilibrium

$$\text{ADP} + \text{phosphate} \rightleftharpoons \text{ATP} + H_2O$$

is normally in the direction of hydrolysis--at equilibrium, there is very little ATP and a large proportion of ADP. In cell respiration, NADH is oxidized to NAD. A great deal of energy is released in this process and this energy drives the reaction in the direction of ATP formation. By coupling these two reactions (NADH oxidation and ATP synthesis) the equilibrium is shifted to favor ATP production. The actual coupling process involves a number of intermediate steps and several enzymes.

3. In ST-28, ΔH is treated as the determinant of an equilibrium position. However, it would be more correct to describe equilibria in terms of "free energy" symbolized by ΔG (sometimes ΔF is used instead). We chose to use ΔH in the Student Text for two reasons. First it is simpler to use and understand and more in keeping with a high school chemistry course. Secondly, ΔH is a useful approximation of ΔG in reactions that do not involve a significant change in entropy, ΔS. (The relationship is: $\Delta H = \Delta G - T\Delta S$.) You may prefer to introduce a more rigorous treatment of energetics involving ΔG. If so, the background information on free energy and equilibria may prove useful.

4. The concept of chemical equilibria is complex and sometimes hard for students to grasp. A simulation game is provided as an optional activity and can be used to give students a clearer understanding of equilibrium. The game follows the background information on free energy and equilibria.

INFORMATION ON FREE ENERGY AND EQUILIBRIA

In ST-23 and ST-24, it was pointed out that chemical reactions either give off energy (exothermic reactions) or require energy (endothermic reactions). Exothermic reactions are characterized by a negative value of ΔH while positive values of ΔH imply an endothermic reaction.

Though the concept of ΔH is an extremely valuable one, it is not the best term for describing the energy change in metabolic reactions. This is because some of the energy released in a chemical reaction is not available in a usable form. In other words, some of ΔH is "wasted" so far as life is concerned. The wasted energy is heat. In a car not all the energy released by the combustion of gasoline is used to propel the car forward since some heat energy is released to the environment. Likewise not all the energy that we get from cell respiration can be used for doing work. The usable energy component of ΔH is called free energy. This kind of energy is "free" to do work. Reactions that occur with a release of free energy are termed exergonic; those that require an input of free energy are endergonic. The term exergonic, comes from two Greek words--"ex" meaning "out" and "ergon" meaning "work." The term "en" means "in."

The new terms can be reviewed with reference to the very first reaction of glycolysis, one in which glucose phosphate is made from glucose.

$$\text{glucose} + \text{phosphate} \rightarrow \text{glucose phosphate} \qquad (1)$$

The reaction can not proceed as written in Equation 1 because it is endergonic. It requires an input of energy to proceed. On the other hand, the hydrolysis of ATP is exergonic

$$\text{ATP} + H_2O \rightarrow \text{ADP} + \text{phosphate} \qquad (2)$$

Life "solves" the problem of making glucose phosphate by coupling, or combining, the two reactions as shown in Equation 3. Thus Equation 2 provides the free energy needed to drive Equation 1. It also provides the phosphate of glucose phosphate.

$$\text{glucose} \xrightarrow{\text{ATP} \curvearrowright \text{ADP}} \text{glucose phosphate} \qquad (3)$$

Many of the important processes of life are endergonic and require coupling with exergonic processes to work. For example, building a protein from amino acids and building a fat from two-carbon compounds are both endergonic processes that can occur only if energy from the breakdown of ATP is supplied.

The concept of free energy is numerically related to the equilibrium constant. In fact, if the free energy change of a reversible reaction is known, K_{eq} can be easily calculated. Under standard conditions (specifically 25 °C, 1 atmosphere pressure), $\Delta G = -RT \ln K_{eq}$.

The "R" is the gas constant (1.987) and "T" in the temperature on the Kelvin scale. The relation is logarithmic.

The following table should make it easier to appreciate how ΔG varies with K_{eq}.

K_{eq}	ΔG Kcal
.001	4.09
.01	2.73
.1	1.36
1.0	0
10	-1.36
100	-2.73
1000	-4.09

SIMULATION OF CHEMICAL EQUILIBRIA

This simulation game is in five versions. The versions represent:

1. exothermic reaction
2. endothermic reaction
3. endothermic reaction with catalyst
4. endothermic reaction with ATP
5. endothermic reaction with removal of product.

The following is true of all five versions.

There are two players and one observer. One player is "reactants" (R) and the otherplayer is "products" (P). The players use tokens to represent molecules. When R holds the tokens, they represent molecules of reactant; when P holds the tokens, they represent molecules of product.

The action in the game consists of passing tokens back and forth from R to P, and from P to R. Passing of tokens from R to P represents the recombination of reactant molecules to form product molecules; passing of tokens from P to R represents the recombination of product molecules to form reactant molecules.

Each version of the game consists of several turns. On each turn, R passes a certain percentage of his tokens to P, and P passes a certain percentage of his tokens to R. This procedure represents the continuous recombination of molecules in an ongoing reversible chemical reaction. The percentage of tokens which R passes to P on each turn simulates the reactivity of the reactant molecules: the higher the percentage, the higher the reactivity of the molecules. Similarly, the percentage of his tokens which P passes to R represents the reactivity of the product molecules.

The function of the observer is to record the numbers of tokens passed on each turn and the total numbers of tokens held on each side after each turn. The observer will call a halt to the version with either (A) the totals have not changed in five turns or (B) one side has only one token after a turn. The situation in which the numbers have not changed in five turns represents chemical equilibrium (A); the situation in which P is reduced to one token (in the final version of the game) is an arbitrary stopping point for the process in which molecules of product are removed from the reaction (B).

The observer can keep score on a score sheet as in the sample shown below.

SAMPLE SCORE SHEET

TURN	R has	R passes	net passed	P passes	P has	OBSERVER holds for P (version V)
	100				0	0
1				0		
2						
10						

The five versions differ from one another only in the percentage of tokens passed by a player on each turn. Whenever a player calculates the number of tokens he is to pass, the procedure is to (1) multiply the number of tokens he has before this turn, by the percentage shown in Table I (2) round down to the next lowest whole number if the product is not a whole number, (3) place the resulting number of tokens in the center of the table, (4) remove from the center of the table the tokens which the other player has placed there and add them to his own pile, and (5) IN VERSION V, P ONLY, deduct a given percentage of his pile and hand the tokens to the oberver for safekeeping. (Each time a player has a turn, he begins with Step 1.)

TABLE 1
PERCENTAGE RULES

	R PASSES:	P PASSES:
VERSION I (EXOTHERMIC)	50%	10%
VERSION II (ENDOTHERMIC)	10%	50%
VERSION III (ENDOTHERMIC WITH CATALYST)	twice as many as in "endothermic," i.e. 20%	twice as many as in "endothermic," i.e. 100%
VERSION IV (ENDOTHERMIC WITH ATP)	four times as many as in "endothermic," i.e. 40%	same as in "endothermic," i.e. 50%
VERSION V (ENDOTHERMIC WITH REMOVAL OF PRODUCT)	same as in "endothermic," i.e. 10%	same as in "endothermic," i.e. 50%, but AFTER EACH TURN, REMOVE 80% OF PILE AND HAND TOKENS TO THE OBSERVER

The results that will be obtained, if R starts with 100 tokens at the beginning of each version, are as shown on the next 5 pages. (Different colored chips or toothpicks can be used for tokens, some representing 10, some 5 and some 1; the observer can act as banker to make change if necessary. The game can also be played without any tokens; players can simply perform calculations and keep a running total on paper.)

TURN	R has	R passes	net passed	P passes	P has	OBSERVER holds for P (Version V)
	100				0	
1		50	50 →	0		
	50				50	
2		25	20 →	5		
	30				70	
3		15	8 →	7		
	22				78	
4		11	4 →	7		
	18				82	
5		9	1 →	8		
	17				83	
6	EQUILIBRIUM→	8	0	8		
	17				83	
7		8	0	8		
	17				83	
8		8	0	8		
	17				83	
9		8	0	8		
	17				83	
10		8	0	8		

VERSION I: Exothermic Reaction

NOTE: The reactants are much more reactive than the products; at equilibrium, there is much more product than reactant.

TURN	R has	R passes	net passed	P passes	P has	OBSERVER holds for P (Version V)
	100				0	
1		10	10 →	0		
	90				10	
2		9	4 →	5		
	86				14	
3		8	1 →	7		
	85				15	
4		8	1 →	7		
	84				16	
5	EQUILIBRIUM →	8	0	8		
	84				16	
6		8	0	8		
	84				16	
7		8	0	8		
	84				16	
8		8	0	8		
	84				16	
9		8	0	8		
10						

VERSION II: Endothermic Reaction

NOTE: The products are much more reactive than the reactants. At equilibrium, there is much more reactant than product.

TURN	R has	R passes	net passed	P passes	P has	OBSERVER holds for P (Version V)
	100				0	
1		20	20 →	0		
	80				20	
2		16	←4	20		
	84				16	
3	EQUILIBRIUM→	16	0	16		
	84				16	
4		16	0	16		
	84				16	
5		16	0	16		
	84				16	
6		16	0	16		
	84				16	
7		16	0	16		
8						
9						
10						

VERSION III: Endothermic Reaction with Catalyst

NOTE: Both reactants and products are twice as reactive as in the ordinary endothermic situation (Version II). Equilibrium is reached sooner, more tokens are passed on each turn, but the proportions of reactants and products at equilibrium are the same as in Version II.

16

TURN	R has	R passes	net passed	P passes	P has	OBSERVER holds for P (Version V)
	100				0	
1		40	40 →	0		
	60				40	
2		24	4 →	20		
	56				44	
3	EQUILIBRIUM →	22	0	22		
	56				44	
4		22	0	22		
	56				44	
5		22	0	22		
	56				44	
6		22	0	22		
	56				44	
7		22	0	22		
8						
9						
10						

VERSION IV: Endothermic Reaction with ATP

NOTE: Reactivity of reactants is four times that in Version II; reactivity of products is equal to that in Version II. The proportion of products at equilibrium is much larger than in Version II.

TURN	R has	R passes	net passed	P passes	P has	OBSERVER holds for P (Version V)
	100				0	0
1		10	10 →	0		
	90				2	8
2		9	8 →	1		
	82				2	16
3		8	7 →	1		
	75				2	23
4		7	6 →	1		
	69				2	29
5		6	5 →	1		
	64				2	34
6		6	5 →	1		
	59				2	39
7		5	4 →	1		
	55				2	43
8		5	4 →	1		
	51				2	47
9		5	4 →	1		
	47				2	51
10		4	3 →	1		
	44				1	55

VERSION V: Endothermic Reaction with Removal of Product

NOTE: Reactivities are the same as in Version II, but some product is removed after each turn. After turn 10, P holds only one token so the version stops. But there are a total of 56 P tokens, 55 of them having been removed from the reaction.

KEY--PROBLEM SET 28:

1. a. exothermic
   b. negative number
2. a. endothermic
   b. exothermic
   c. forward: positive
      reverse: negative
3. a. exothermic
   b. endothermic
   c. forward: negative
   d. reverse: positive

LESSON 29: DAILY FOOD INTAKE

RATIONALE:

This lesson, and the two that follow, serve to review and to complete the study of the essential features of a diet that is beneficial to health. The activity provides an opportunity for the students to learn about the nutrient content of the foods that they normally eat, and allows them to begin thinking about how they can improve their diets.

OBJECTIVE:

The student will determine the energy provided by and the quantities of specific nutrients contained in his daily diet.

SUGGESTIONS:

1. Students who complete the worksheet may wish to read Section 30 of the Student Text in preparation for Laboratory Activity 30.

2. The student should be advised to wear clothing appropriate for the measurements of skinfold thickness to be made in Laboratory Activity 30 (see page 102 of the Laboratory Manual). Clothing such as dresses or coveralls may present problems.

INFORMATION ON ACTIVITY 29:

TEACHING NOTES:

1. In this activity the students determine the total amounts of various essential nutrients in their daily diets. These data will be compared to recommended daily allowances in Activity 31, where the students use the results of Activities 24, 29 and 30 in designing their optimal diets.

2. Anticipated time: one to two periods.

3. The students should make a list before they come to class of all the foods that they eat during a particular day. It is suggested that the students carry an index card that can be filled out as the day progresses.

4. The activity may be augmented by recording food intake over longer periods of time (up to three days). Using this approach, it is generally easier to detect diets that are deficient in an essential nutrient. As discussed in Section 30-1, nutrient deficiencies on a particular day are not important if sufficient amounts of each nutrient are supplied over longer periods of time. The students may also be interested in evaluating the diets of friends, family members or members of athletic teams.

5. A copy of Worksheet 29 is included here for possible reproduction.

MATERIALS:

Bowes, Anna deP. and Charles F. Church. Food Values of Portions Commonly Used. J. B. Lippincott, Philadelphia, latest edition (several copies).

Nutritive Value of Foods. Home and Garden Bulletin No. 72. U.S. Dept. of Agriculture (one per student).

BACKGROUND INFORMATION ON WORKSHEET 29:

A complete determination of nutrient totals in the diet can be an imposing task. The following is provided so that you can anticipate and avoid certain problem areas.

The students should use Nutritive Value of Foods to obtain information on all the nutrients except the amino acids. Let us suppose that a student wishes to find data on the egg he had for breakfast. He would first consult the CONTENTS, appearing at the front of the book. He would then turn to page 9 and find the following table.

Food, app		Water	Food energy	Protein	Fat	Fatty acids			Carbohydrate	Calcium	Iron	Vitamin A value	Thiamin	Riboflavin	Niacin	Ascorbic acid
						Saturated (total)	Unsaturated									
							Oleic	Linoleic								
EGGS																
Eggs, large, 2																
Raw or coo d:																
Whole, wit	50	74	80	6	6	2	3	Trace	Trace	27	1.1	590	.05	.15	Trace	0
White of e	33	88	15	4	Trace	.....	.....	.....	Trace	3	Trace	0	Trace	.09	Trace	0
Yolk of egg	7	51	60	3	5	2	2	Trace	Trace	24	.9	580	.04	.07	Trace	0
Scrambled and fat	64	72	110	7	8	3	3	Trace	1	51	1.1	690	.05	.18	Trace	0

The next step is to transfer the nutrient values given for one whole egg to the appropriate columns of Worksheet 21. At this point students should be cautioned to pay close attention to the amounts of food (approx. portion) given in the table. Frequently the amount given differs from the amount eaten and appropriate adjustments must be made in the nutrient values. A visual display of measuring cups (i.e., 1 cup, $\frac{1}{2}$ cup and $\frac{1}{4}$ cup) may be of some use in estimating quantities of food.

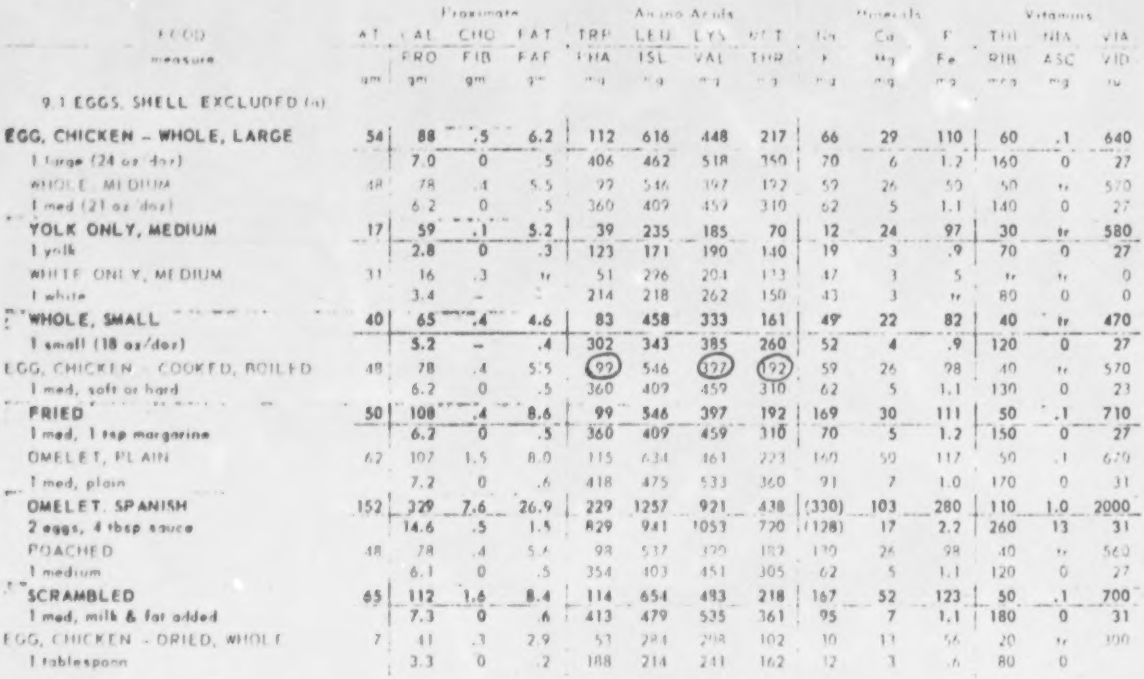
NAME: ______________________________

WORKSHEET 29

Food, approx. portion	Food energy (Cal)	Protein (g)	Amino Acids			Total Fat (g)	Fatty Acids		Carbohydrate (g)	Calcium (mg)	Iron (mg)	Vitamin A (IU)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
			TRP (mg)	LYS (mg)	MET (mg)		Saturated (g)	Linoleic (g)								
TOTAL																

Note that the students have been asked to record only the values for "saturated" and "linoleic" under the heading "fatty acids"; oleic has been excluded. The reason for this is that when the students are creating their optimal diets, an important consideration is the ratio of polyunsaturated fatty acids (represented by linoleic) to saturated fatty acids. Since oleic acid is a monounsaturated fatty acid it is not necessary for this comparison.

In order to complete the listing for amino acids on the worksheet, the student must refer to the second publication, Food Values of Portions Commonly Used. There is a detailed index in the back of the book. Upon looking up "egg" and turning to page 30 the student will encounter the following table.



FOOD measure	WT	CAL PRO	CHO FIB	FAT FAF	TRP PHA	LEU ISL	LYS VAL	MET THR	Na K	Ca Mg	P Fe	THI RIB	NIA ASC	VIA VID
		Proximate			Amino Acids				Minerals			Vitamins		
	gm	gm	gm	gm	mg	mg	mg	mg	mg	mg	mg	mcg	mg	IU
9.1 EGGS, SHELL EXCLUDED (a)														
EGG, CHICKEN – WHOLE, LARGE	54	88	.5	6.2	112	616	448	217	66	29	110	60	.1	640
1 large (24 oz/doz)		7.0	0	.5	406	462	518	350	70	6	1.2	160	0	27
WHOLE, MEDIUM	48	78	.4	5.5	97	546	397	192	59	26	98	50	tr	570
1 med (21 oz/doz)		6.2	0	.5	360	409	459	310	62	5	1.1	140	0	27
YOLK ONLY, MEDIUM	17	59	.1	5.2	39	235	185	70	12	24	97	30	tr	580
1 yolk		2.8	0	.3	123	171	190	140	19	3	.9	70	0	27
WHITE ONLY, MEDIUM	31	16	.3	tr	51	226	204	113	47	3	5	tr	tr	0
1 white		3.4	–	–	214	218	262	150	43	3	tr	80	0	0
WHOLE, SMALL	40	65	.4	4.6	83	458	333	161	49	22	82	40	tr	470
1 small (18 oz/doz)		5.2	–	.4	302	343	385	260	52	4	.9	120	0	27
EGG, CHICKEN – COOKED, BOILED	48	78	.4	5.5	97	546	397	192	59	26	98	40	tr	570
1 med, soft or hard		6.2	0	.5	360	409	459	310	62	5	1.1	130	0	23
FRIED	50	108	.4	8.6	99	546	397	192	169	30	111	50	.1	710
1 med, 1 tsp margarine		6.2	0	.5	360	409	459	310	70	5	1.2	150	0	27
OMELET, PLAIN	62	107	1.5	8.0	115	634	461	223	160	50	117	50	.1	670
1 med, plain		7.2	0	.6	418	475	533	360	91	7	1.0	170	0	31
OMELET, SPANISH	152	329	7.6	26.9	229	1257	921	438	(330)	103	280	110	1.0	2000
2 eggs, 4 tbsp sauce		14.6	.5	1.5	829	941	1053	720	(128)	17	2.2	260	13	31
POACHED	48	78	.4	5.4	98	537	399	182	130	26	98	40	tr	560
1 medium		6.1	0	.5	354	403	451	305	62	5	1.1	120	0	27
SCRAMBLED	65	112	1.6	8.4	114	654	493	218	167	52	123	50	.1	700
1 med, milk & fat added		7.3	0	.6	413	479	535	361	95	7	1.1	180	0	31
EGG, CHICKEN – DRIED, WHOLE	7	41	.3	2.9	53	284	298	102	10	11	56	20	tr	300
1 tablespoon		3.3	0	.2	188	214	241	162	12	3	.6	80	0	

He should select the appropriate entry, i.e., the particular type of egg, and transfer the necessary information for amino acids to his worksheet. For example, for a boiled egg the values the student is concerned with are those circled above. Again, the students should be cautioned to compare the portions used in the book to those which they actually have eaten. Call attention to the fact that each food is a two-line entry, and that TRP, LYS and MET are on the first line.

Because there are only a small number of copies of the publication Food Values of Portions Commonly Used, students will have to take turns using it. This should not prove too large a problem since students not using this publication can be looking up the other necessary values in Nutritive Values of Foods.

The students can be expected to have two kinds of difficulty. One involves deciding which of several entries to use. For example, did a slice of white bread (soft-crumb type) come from a loaf with 18, 22, 24 or 28 slices? The best that can be done in such cases is to select some intermediate value, rather than one of the extremes.

Another problem is remembering to include all the foods eaten. For example, a hamburger "with everything" is more than meat and a bun. It includes lettuce, onions, relish (found in the miscellaneous section under "pickles"), catsup (found under "tomato") and mayonnaise (found in the fats and oils section under "salad dressings"). Even finding the hamburger bun may be a problem. It is listed in the grain section under "rolls, frankfurter or hamburger."

The preceding example was selected because of its difficulty. Most foods present fewer problems.

LESSON 30: (A) RECOMMENDED DAILY ALLOWANCES
(B) OVERWEIGHT AND OBESE
(C) IDEAL WEIGHT

RATIONALE:

In order to understand the essential aspects of an optimal diet, the students must become acquainted with Recommended Daily Allowances and the distinction between the terms "overweight" and "obese." In addition, a determination of ideal weight is necessary so that the students can correctly design their own optimal diets in Activity 31.

OBJECTIVES:

The student will:

- explain the importance of Recommended Daily Allowances in the evaluation of a diet.
- distinguish between the terms overweight and obese.
- determine his ideal body weight from measurements of skinfold thickness.

SEQUENCE: ST-30, LA-30

SUGGESTIONS:

1. Diet foods could be brought to class for a discussion of the nutrient values of the ingredients. Comparisons may be made to regular foods.

2. The pros and cons of different methods of losing and gaining weight could be discussed. Such methods include special liquid foods for gaining or losing weight, increasing or decreasing caloric intake, and exercising.

3. It should be emphasized that the recommendations for ideal weight (12 to 16% fat for males, and 18 to 24% fat for females) may not reflect the aesthetic ideals of some cultures. For example, some Polynesian populations (Hawaiian, Tongan, Samoan) consider higher fat percentages to be more aesthetically appealing.

INFORMATION ON LABORATORY ACTIVITY 30:

TEACHING NOTES:

1. The purpose of this activity is for the students to obtain measurements which can be used to determine their percentage body fat. This percentage is then used to determine the ideal body weight. In Worksheet 31, ideal body weight is used in establishing the student's optimal diet.

2. Anticipated time: one period.

3. The students may wish to augment the activity by using the calipers to determine the ideal weights of members of their families, members of school athletic teams, etc.

4. Two types of calipers may be necessary. One is designed for people of average weight, while the other is for obese individuals. Special instructions are provided in Procedure Steps 4 and 5 and in the Preparation of Materials section.

5. You may wish to have the students assemble their own calipers.

6. The formulas used in Step 13 may be derived from the following general expression.

$$\text{Ideal body weight} = \text{Lean body weight} + \text{Ideal amount of fat}$$

Assuming that the ideal amount of fat for women and men is, respectively, 21% and 14% of ideal body weight (the midpoints of the ranges given in Section 30-2), our initial expression may be restated algebraically as follows, where X = ideal body weight and L = lean body weight.

Females: $X = L + .21X$ Males: $X = L + .14X$

Solving for X in each case:

$$X - .21X = L \qquad\qquad X - .14X = L$$

$$.79X = L \qquad\qquad .86X = L$$

Females: $X = 1.27L$ Males: $X = 1.16L$

7. For a quick check of student calculations, the following general formulas may be used.

$$\text{Females:}\quad X = 1.27(\text{present weight in kg})(1 - \frac{P}{100\%})$$

$$\text{Males:}\quad X = 1.16(\text{present weight in kg})(1 - \frac{P}{100\%})$$

8. It should be emphasized that ideal weight cannot be completely objectified or defined in absolute terms.

9. Females normally have a thicker subcutaneous fat layer than males. Thus healthy females generally have significantly higher percentages of fat than healthy males.

MATERIALS: (for 10 set-ups)

10 millimeter rulers
10 skinfold calipers
scale for measuring body weight

PREPARATION OF SKINFOLD CALIPERS:

Materials needed for each "fat grabber":

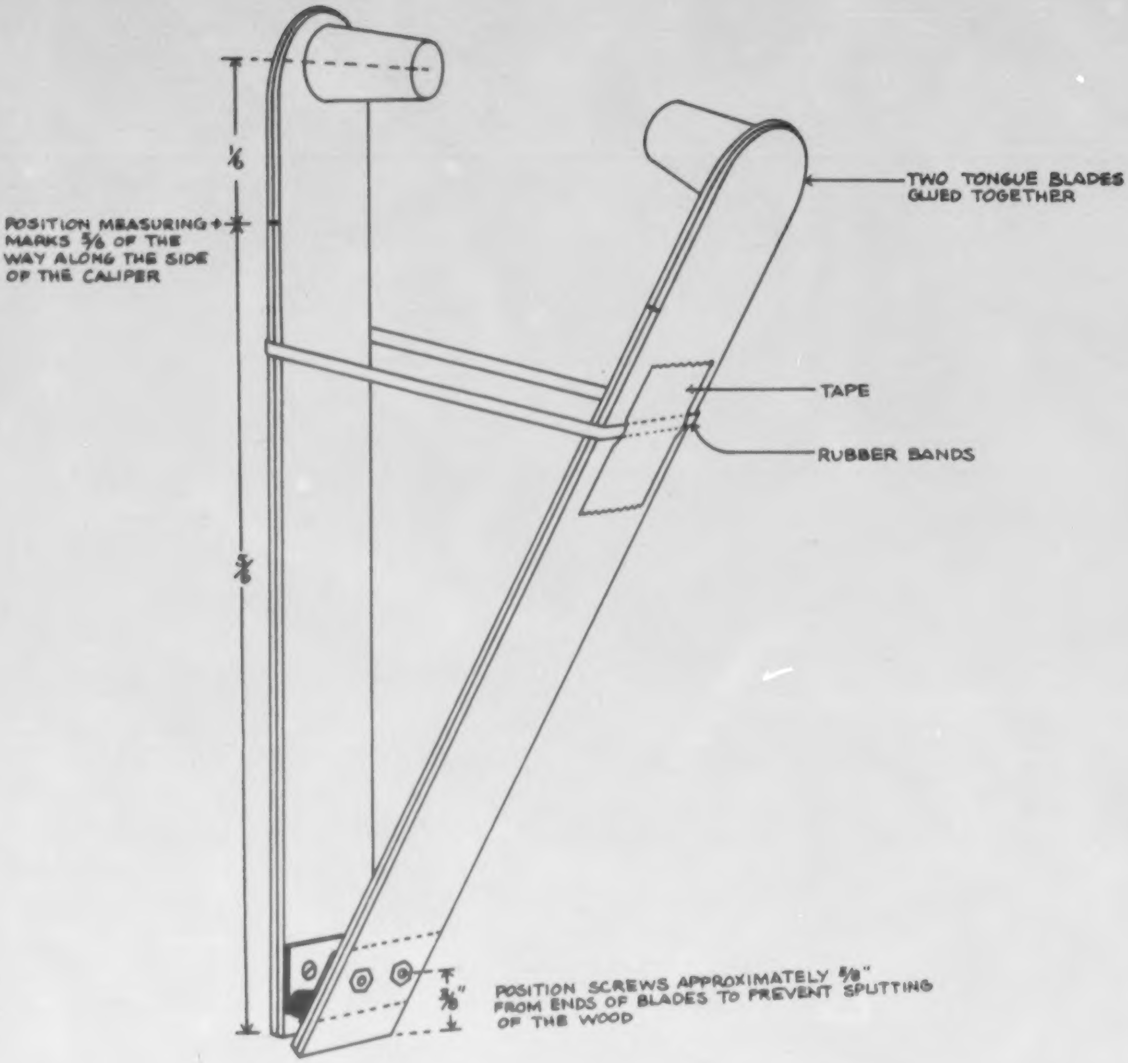
4 tongue blades (from pharmacy)
2 rubber stoppers, #000
1 hinge, 3/4", with 4 screws
rubber bands
white glue
tape

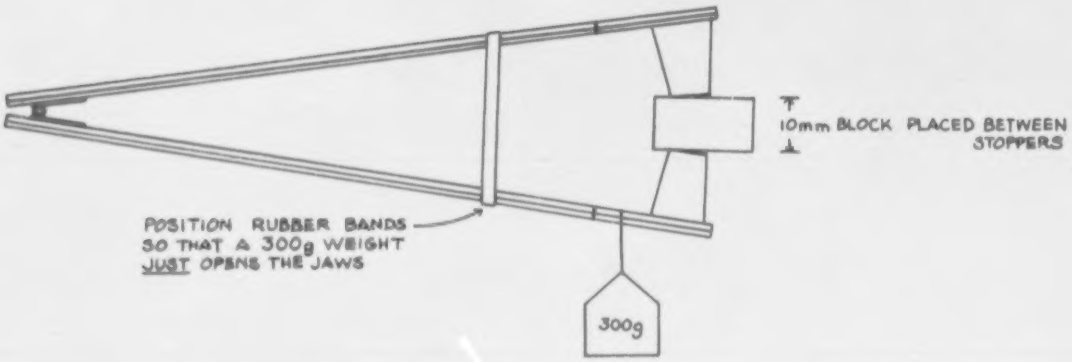
Instructions for assembly (refer to sketch):

1. Make four tongue blades into two double-thickness blades by cementing them together with white glue.

2. After allowing the glue to dry (an hour should be sufficient), trim the hinge ends of the blades so that they are flat.

3. Attach the hinge as shown in the sketch. The screws should be placed approximately 3/8" from the ends of the blades. (If they are too close


1/6
POSITION MEASURING MARKS 5/6 OF THE WAY ALONG THE SIDE OF THE CALIPER
5/6
TWO TONGUE BLADES GLUED TOGETHER
TAPE
RUBBER BANDS
3/8"
POSITION SCREWS APPROXIMATELY 3/8" FROM ENDS OF BLADES TO PREVENT SPLITTING OF THE WOOD


10mm BLOCK PLACED BETWEEN STOPPERS
POSITION RUBBER BANDS SO THAT A 300g WEIGHT JUST OPENS THE JAWS
300g

to the edge, the wood may split.) Pilot holes should prevent the wood from splitting.

4. Attach the stoppers as shown with white glue. Be sure that the stopper ends meet evenly when the blades are closed.

5. Place measuring marks on the blades as shown, five-sixths of the way along the sides of the caliper. It is useful to place the marks on both sides of each blade (four marks altogether).

6. To adjust the closing tension, insert a 10-mm block between the stopper ends (see sketch).

7. Place rubber bands about one-half to three-fourths of the way up in such a position and number that a 300-g weight hung from the end just opens the jaws. Tape the bands in position to prevent slippage.

8. One or two "low-tension" calipers should be made for obese individuals. This is done by adjusting the tension using a 14-mm block in place of the 10-mm block.

LESSON 31: THE OPTIMAL DIET

RATIONALE:

A primary objective of the Nutrition Unit is to provide information concerning the essential features of a diet that is beneficial to health. ST-31 and Activity 31 summarize the information on nutrient requirements discussed in previous sections. The students use this information and the data from Activities 24, 29 and 30 in designing diets for themselves that provide the optimal intake of nutrients and calories.

OBJECTIVES:

The student will

- list the nutrients required in an optimal diet, and explain why at least six of these are necessary for the maintenance of health.
- define roughage and explain why it is a desirable component of the diet.
- list two sources of roughage.
- explain why it is important to consider the amounts of salt, sugar and saturated fatty acids when designing an optimal diet.

- study the nutrient content of a meal and suggest changes that will bring it closer to the optimum.
- design an optimal diet.

SEQUENCE: ST-31; Activity 31

SUGGESTIONS:

1. Many factors may affect what constitutes an optimal diet, such as personal preferences, food sources available, etc. In Biomedical Social Science Unit II, the students study the diets and health of various cultures. (For further information, see Social Science Student Text, Unit II, Part One, pp. 144-45.) Some of their findings might be discussed in relation to the requirements for optimal diets that are set forth in the Science Student Text. For example, were there cultures in which the nutrient intake of the people deviated greatly from the requirements for optimal diet discussed in this unit? If so, were dietary deficiency diseases also seen frequently in these cultures? If not, what are possible explanations?

2. A possible supplement to this series of lessons would be a research project on diseases and special diets. Students could be asked to do library research on the cause, nature and treatment of a disease of their choice, with specific reference to dietary therapy and preventive maintenance. The students may have close relatives or friends on special diets, and may be curious about the purposes of the diets.

Among the diseases or conditions that might be researched are diabetes, hypertension, heart disease, atherosclerosis, obesity, phenylketonuria, cystic fibrosis, hepatitis, chronic renal failure and lactose intolerance. Students could be asked to report on their findings during Lesson 33, since there is no scheduled laboratory activity for that lesson.

3. LA-34 calls for agar for a microbiology investigation. You may wish to prepare the agar in advance.

INFORMATION ON ACTIVITY 31:

TEACHING NOTES:

1. In this activity the students use results from Activities 24, 29 and 30 in designing their optimal diets. A diet may be considered optimal if it meets the following criteria.

a. The diet should have the recommended amounts of each essential nutrient and, coincidentally, the proper number of calories.

b. The diet should have the proper balance of nutrients (for example, three to four times as much carbohydrate as fat).

c. The foods selected should be enjoyable to eat.

2. Anticipated time: one to two periods.

3. The activity may be augmented by having the students design three-day diets. This approach makes it somewhat easier to acquire the proper amounts of each nutrient. In addition, a three-day diet permits a greater variety of foods, as well as more experience in selecting nutritious foods.

4. The recommended dietary allowances provided in Part I are average values for persons 15 to 18 years of age. The values given for males and females differ in part because the average male in this age group is heavier than the average female.

5. Students could be asked to "price" their real and optimal diets, and to compare the two on an economic basis. A similar approach is used in Activity 39.

6. You may wish to supply the students with additional blank copies of Worksheet 29.

MATERIALS:

Same as for Activity 29.

LESSON 32: (A) DIABETES MELLITUS

(B) GLUCOSE TOLERANCE TEST

RATIONALE:

In Activity 31 the students designed optimal diets for themselves. It was pointed out that an optimal diet depends upon an individual and his physiology. There are many diseases which alter human physiology and necessitate a modified diet. Diabetes mellitus is an example and is considered in ST-32. As of 1974, diabetes and its complications were the third most common cause of death in this country. In LA-32, the students perform one of the clinical tests for blood glucose used to detect diabetes.

OBJECTIVES:

The students will:

- define diabetes mellitus.
- explain the physiological reasons for two of the symptoms of diabetes mellitus (i.e., sugar in the urine and a high blood glucose level).
- list at least two serious complications of diabetes mellitus.
- list two clinical tests that are employed in the diagnosis of diabetes mellitus.
- define "fasting blood-glucose level" and explain its relationship to the diagnosis of diabetes mellitus.
- list two methods employed in the treatment of diabetes.
- list two ways in which the diet prescribed for a diabetic differs from the "optimal diet" for a normal individual.
- describe the system of "food exchange groups" used to help diabetics control their diets.
- explain how to perform a glucose test on simulated serum samples and use the results to determine whether a patient is diabetic.

SEQUENCE: ST-32; LA-32

SUGGESTIONS:

1. It has been hypothesized that there is an association between an increase in the consumption of sugar in the United States and the incidence of diabetes. One or more students may wish to do some library research on this topic and make a report to the class.

2. If any of the students have had a glucose-tolerance test performed, they might share their recollections of the experience with the class.

INFORMATION ON LABORATORY ACTIVITY 32:

TEACHING NOTES:

1. The purpose of this activity is to provide the students with the opportunity to perform a clinical glucose-tolerance test.

2. Anticipated time: one period.

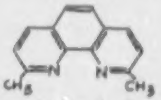
3. This activity may be extended by having the students make up their own

calibration curves for the colorimeter and/or having them test a greater number of samples. (Also, see Teaching Notes 7 and 9.)

4. The activity may be shortened by decreasing the number of samples tested.

5. This test involves the reduction of a cupric-neocuproine chelate (blue-green) by glucose in an alkaline solution, to give a cuprous-neocuproine complex (yellow-orange). (A chelate is a structure formed by the interaction between an organic compound and a metal such as copper.) The neocuproine reagent solution contains the cupric complex, and the sodium carbonate solution provides the basic pH.

$$\begin{array}{cccccc} \text{glucose} & + & Cu^{+2}\text{-chelate} & \xrightarrow{\text{heat}, OH^-} & \text{gluconic acid} & + \; Cu^{+}\text{-chelate} \\ (C_6H_{12}O_6) & & \text{(blue-green)} & & (C_6H_{12}O_7) & \text{(yellow-orange)} \end{array}$$

(The structural formula for neocuproine is  .)

The test was adapted from a glucose method developed for use with a multichannel biochemical analyzer. A detailed description of the test was released by Technicon Instruments Corporation (Tarrytown, N.Y. 10591) in June 1974. Refer to Technicon Method No. SF4-0002FF4.

6. In order to simplify the instructions, the procedure for this activity is written as if each student is to analyze one set of simulated serum samples. In view of economy and time, it would probably be wise to divide the class into teams of three and have each member of a team analyze one of the samples from the set assigned to the team. (The materials list is based on this alternative.) If the team option is chosen, then students should be instructed to decide how to divide the tasks before they begin the activity.

7. There should be at least two sets of simulated serum samples--one set consistent with a diagnosis of diabetes and another set consistent with a diagnosis of normal. Each set should contain three simulated serum samples, each sample representing blood drawn at a different timed interval during the glucose tolerance test. If you wish to make more unknowns, refer to the glucose-tolerance curves for normal and diabetic patients in ST-32, p. 181. Instructions on how to make up the samples may be found under "Preparation of Reagents."

8. All the samples must be diluted by a factor of three before the test is run. This dilution is necessary because at the wavelengths produced by the photocell in the BIP test well, the percentage of error in the calibration curve is large for glucose concentrations greater than 100 mg/100 ml. By diluting the samples, all the values will be brought within a range of 0 to 100 mg/100 ml.

9. It is common procedure for a patient's urine to be tested qualitatively for glucose before deciding whether or not to perform a glucose-tolerance test. (However, a glucose-tolerance test is performed without a previous qualitative test, for example, in testing for glucose in hypoglycemic patients.) If the results of this preliminary test show a high concentration of sugar, the glucose-tolerance test is then done. It would be possible to add an extra "part" to this activity by including this preliminary test for glucose. You would need one simulated urine sample for each set of simulated serum samples. The results of such a test could be used to corroborate the diagnoses based on the glucose-tolerance tests. If you elect to incorporate the urine test into the activity, refer to instructions on how to make up the urine samples under "Preparation of Reagents." "Clinistix" strips (used for testing glucose) are available from Ames Company, Division of Miles Laboratories, Inc., Elkhart, Indiana 46514. (They are also distributed through companies such as Scientific Products.) The strips are designated "Clinistix, Reagent Strips, 10-second Test for Urine Sugar." An alternative to "Clinistrix" strips is "Testape," marketed by Eli Lilly and Co., 277 Park Ave., N.Y. 10017. You might also check in the telephone directory to see whether the company has a regional office in your area.

10. If you make up the serum samples, neocuproine or simulated urine solutions in advance of the activity, store them in the refrigerator and allow time for them to warm up to room temperature before use.

11. As in LA-27, the calibration line is curved rather than straight. In fact, all calibration curves are linear only over a certain concentration range, and the calibration lines we have used thus far have shown only the linear portion of the range.

MATERIALS: (per 10 set-ups)

- 0.32 g neocuproine (2,9-dimethyl-1,10-phenanthroline)
- 15.5 g sodium carbonate ($Na_2CO_3 \cdot H_2O$)
- 2.0 g glucose (or dextrose)
- 4.0 g sodium benzoate
- 15.0 ml ethyl alcohol, denatured
- 70 cuvets, 16 x 125 mm, Pyrex
- 40 pipets, 1-ml
- 30 pipets, 10-ml
- 20 beakers, 50-ml
- 10 beakers, 250-ml
- 10 test tube racks
- 10 thermometers
- 10 ring stands with ring
- 10 wire gauze
- 10 graduated cylinders, 10-ml
- 10 gas burners
- 10 BIP colorimeters
- matches
- 10 glass-marking pencils
- paper tissues

PREPARATION OF REAGENTS:

Neocuproine reagent, 200 ml: Dissolve 0.32 ± .01 g neocuproine in 15 ± 1 ml of denatured ethyl alcohol. Add enough water to make 200 ml. Dissolve 0.16 ± .01 g copper (II) sulfate ($CuSO_4\ 5H_2O$) in the solution. Store in a stoppered flask in the refrigerator. Should keep for about one week. If any color change is noted during storage time, a new batch of reagent should be made up.

0.25 M sodium carbonate solution, 500 ml: 35.8 ± .1 g sodium carbonate ($Na_2CO_3 \cdot 10H_2O$) + sufficient water to make 500 ml.

Simulated serum samples, 200 ml: You will need to make up six separate simulated samples, three for the "normal" set and three for the "diabetic" set. To do this, dissolve 2 ± .01 g glucose and 4 ± .1 g of sodium benzoate ($NaCr_7H_5O_2$) in sufficient water to make 200 ± 5 ml. Make up the samples using this glucose solution and water in the amounts given in the following table.

All sample solutions should be placed in coded flasks and stored in the refrigerator. They will keep for about one week.

	Simulated Serum Sample (mg glucose/100 ml)	Code	Glucose Solution (ml)	Water (ml)
Normal Set	100	F_1	10 ± .1	90 ± 1
	150	I_1	15 ± .1	85 ± 1
	100	III_1	10 ± .1	90 ± 1
Diabetic Set	150	F_2	15 ± .1	85 ± 1
	300	I_2	30 ± .1	70 ± 1
	200	III_2	20 ± .1	80 ± 1

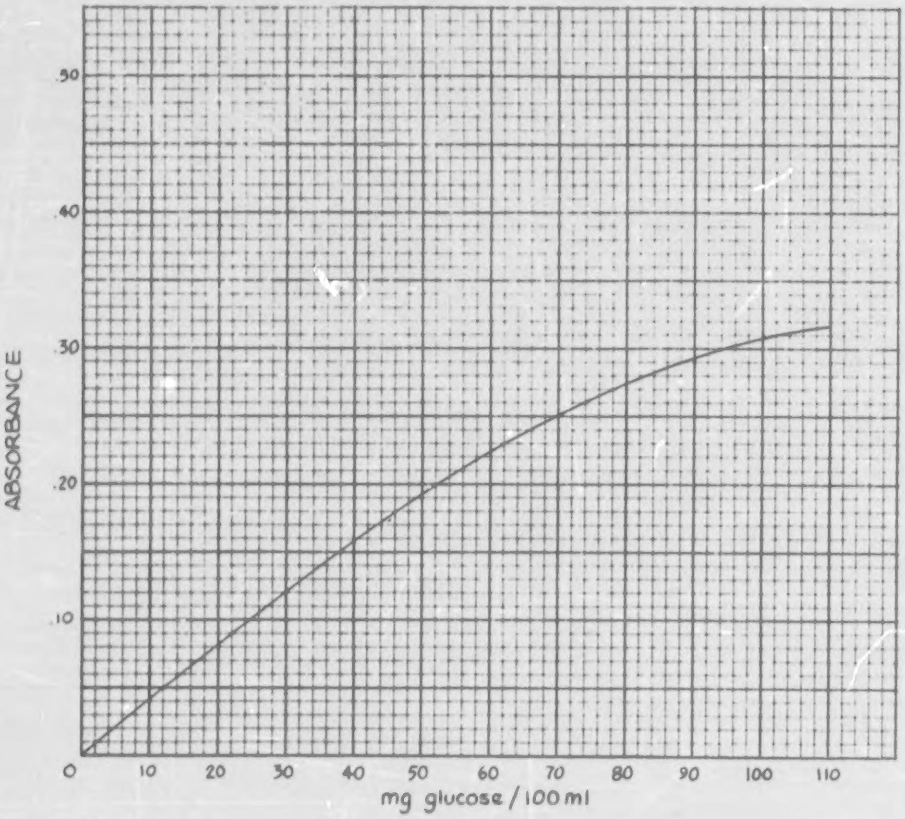
Samples coded F_1 and F_2 correspond to fasting levels of glucose. I_1 and I_2 correspond to glucose levels one hour after ingesting 75 g of glucose and III_1 and III_2 correspond to glucose levels three hours after ingesting 75 g of glucose.

NOTE: No attempt has been made to simulate the yellowish color of serum. This is because when the reagent solution is heated, some yellow color is produced. If additional yellow is added to the serum samples, the samples will be too "dark" to read with the BIP colorimeter.

Simulated urine samples (optional): Distilled water may be used for the simulated urine sample to match the "normal" set of serum samples. For the "diabetic" set, use 100 ml of 1% glucose solution. If you wish to add yellow food coloring to these samples it will not interfere with the test.

ANTICIPATED RESULTS:

A copy of the calibration curve we obtained appears below.



Three unknowns were analyzed to check the accuracy of the curve. The results obtained and the actual glucose concentrations of the unknowns appear below.

Unknown	Lab Result mg/100 ml	Actual Glucose Conc. mg/100 ml
#1	26	25
#2	103	100
#3	158	150

ANSWERS TO DISCUSSION QUESTIONS:

1. Comparison of results with the glucose-tolerance curves for a normal person and a diabetic (ST-32, p. 181) is the best way to make this decision. All three glucose values are significantly higher in the diabetic than the normal samples.

2. It was necessary to dilute the samples threefold to bring the glucose concentrations of all samples within the range of the calibration curve provided, i.e., 0 to 100 mg glucose/100 ml.

3. Other sources of helpful information might be family history, urine test for glucose, information on frequency and volume of urine output, history of frequent thirst, etc.

4. Sources of error in this activity include measurement error such as in pipetting, inaccurate colorimetric readings, error in making up the simulated samples, error in reading the calibration curve, error in the calibration curve itself, error due to using a calibration curve constructed with a different colorimeter, calculation error, etc.

LESSON 33: (A) OBESITY

(B) REVIEW

RATIONALE:

In ST-32, we considered the manner in which a disease (diabetes mellitus) may alter the optimal diet of an individual, and conversely how the individual's diet may be altered in treatment of the disease. ST-33 discusses the causes and dietary treatment of obesity. Obesity is of special medical concern and was chosen for several reasons: (1) it is a common condition, (2) it is associated with a number of other diseases such as atherosclerosis, diabetes, hypertension and arthritis, (3) there are many misconceptions about the best way to lose weight.

OBJECTIVES:

The student will:

- state the primary cause of obesity
- list at least three medical complications of obesity
- list two ways in which obesity is treated
- list two reasons why it is not desirable to lose more than 2 to 3 pounds a week
- calculate the number of calories that should be included in the diet of Mr. X, if he is to lose 2 lbs/week when given (1) his daily energy expenditure in calories, (2) his daily calorie intake (3) his present weight and (4) his ideal weight.
- explain why a diet that contains too little carbohydrate is undesirable
- define hypothyroidism

SEQUENCE: ST-33

SUGGESTIONS:

1. The primary reason for weight gain is that calorie intake exceeds calorie expenditure. However, there are many reasons why this may happen, some of them psychological. You may want to lead an open discussion on the question of why some people "eat too much and exercise too little."

2. There are a great many diets on the market, each recommending a surefire way in which to lose weight. It might be interesting to consider how well these diets measure up to the requirements given for an optimal diet. Also,

the students can evaluate diets based on the recommendations presented in this lesson for treatment of obesity.

INFORMATION ON OBESITY:

While definitions of obesity are somewhat arbitrary and artificial, the table below shows commonly accepted criteria.

% BODY FAT	CONDITION
12-16% male 18-24% female	ideal body weight
27-36% male 35-44% female	slight to moderate obesity
37% and over male 45% and over female	moderate to marked obesity

Using the criteria shown in the table, approximately one-fourth of the U.S. population can be considered obese. Obesity causes two types of medical problems (1) increases the risk of other medical conditions and (2) causes symptoms directly due to excess weight. The following conditions are more common in the obese.

1. diabetes
2. gallbladder disease
3. premature atherosclerosis
4. hypertension

These symptoms are frequent in obese people.

1. shortness of breath up on exertion
2. general body aching
3. tiredness
4. painful joints, especially the knees and ankles.

Shortness of breath results because the weight of fat on the chest wall reduces the vital capacity; in addition, more work is performed in climbing stairs, etc. General body aching and tiredness are related in some way to the mechanical inefficiences caused by excess fat. Painful joints in the lower extremities are simply the result of joints supporting too much weight.

Obesity may be caused by various medical disorders, but in at least 95 out of 100 cases the cause is an intake of more calories than are expended. An obese person may maintain a steady weight on fewer calories than are needed for an ideal body weight. This is largely because obese people tend to be very inactive physically.

Why do people become obese? This answer is very complex. A number of factors will be discussed briefly.

1. "It runs in my family." There are genetic factors in some cases, but these are not well understood. Eating patterns are conditioned in early childhood. In many cases, parents believe a plump baby is a healthy baby and feed their infants too much food.

2. "Its due to low thyroid." This is an extremely common fallacy and probably grew out of the observation that obese people have lower BMR's than people with ideal body weights. However, BMR calculations are based on body surface area (which is increased in obesity) while metabolic activity is largely due to muscle mass. The calculated BMR therefore gives a false index.

3. "Even if I stick to a diet I gain weight." This is the standard cop-out. The usual reducing diet is not easily followed, mainly because low-calorie foods are expensive or not very palatable.

4. "Fat people are happier." Maybe so, but they are not healthier.

We are constantly bombarded by pressures to eat, both social and from advertising. The following summary should help most people attain an ideal body weight without "dieting."

1. Avoid sugars and refined carbohydrates.

2. Avoid desserts such as cake, pie and ice cream.

3. Avoid snack foods.

4. Limit fatty foods such as cheese, fatty meats, rich gravies, etc.

5. Exercise regularly and avoid elevators and automobiles as much as possible.

KEY--REVIEW SET 33:

1. a. Energy may neither be created nor destroyed. b. yes

2. b, c, d, f

3. a. endothermic; b. yes; c. absorbed; d. the sun (or solar energy)

4. a. 37.5 kcal; b. 3.75 kcal/g; 3.75 Cal/g; c. 3.75 Cal/g

5. a. -1303 kcal/mole; b. exothermic; c. 114 amu; d. -11.4 Cal/g

6. See Section 26-1.

7. a. Glycolysis--glucose is converted to pyruvic acid; 2 ATP's are gained. In the rest of cell respiration, considerably more energy is obtained in the form of ATP; CO_2 is released, oxygen is consumed.

b. Cell respiration releases the energy from nutrients.

8. a. catalysis--speed up reactions.

b. assist enzymes in catalysis

c. Breakdown to glycerol and fatty acids. Both feed into the metabolic pathway of cell respiration.

d. House the enzymes of cell respiration and serve to organize the parts of the process.

9. In endothermic reactions, ΔH_r is positive and K_{eq} tends to be <1. In exothermic reactions, ΔH_r is negative, and K_{eq} ends to be >1.

10. a. $K_{eq} < 1$; b. ΔH is positive; c. endothermic; d. nothing can be inferred.

11. a. $ATP + H_2O \longrightarrow ADP + phosphate$; b. Provides energy needed for many endothermic reactions; c. exothermic; d. K_{eq} is a large number.

12. chemical equilibria--dynamic; diffusion--dynamic; motionless object--static

13. No. There is great variation in dietary needs among individuals. Children need less nutrients than adults; people with certain medical problems may need increased amounts of specific nutrients, etc.

14. Sodium chloride. It occurs in many foods, particularly packaged varieties.

15. indigestion, stomach ache, nausea, etc.

16. It is likely that an excess of saturated fatty acids results in an increase in cholesterol in our blood. Increased cholesterol level probably increases our chance of heart disease.

17. Chocolate, coconut, fatty meats, whole-milk products (ice cream, cheese, butter, etc.).

18. a. Roughage aids in maintaining the proper water content of the feces. Such "fiber" possibly prevents certain diseases of the alimentary tract.

b. It is found in fruits, vegetables, and whole-grained breads and cereals.

19. It is a disease characterized by high blood-sugar level. The body is unable to use glucose properly.

20. Yes. Obese people may not be able to control their food intake for psychological, or physiological reasons. In either case, this condition is a medical problem and can be termed an illness.

21. To expend more energy than we consume. This may be achieved by eating less "fattening" foods and by exercising more often or more strenuously.

LESSON 34: (A) INTRODUCTION TO MICROBIOLOGY
(B) FOODBORNE DISEASE

RATIONALE:

This is the first lesson in the sequence on food and waterborne disease. There are two topics of major importance. First, any discussion of food and nutrition should include the health problems associated with harmful microbes and chemicals that may be found in food or water. Second, the alteration of foods by processing has health implications. Lessons 34 through 39 deal with these problems. ST-34 introduces microbiology and considers the recognition and prevention of some forms of disease related to the growth of microorganisms in food. LA-34 introduces microbiological laboratory techniques.

OBJECTIVES:

The student will:

- define microbe and name three major types of microbes.
- list at least one useful function of intestinal bacteria and of bacteria used in the food industry.
- list three ways in which foodborne diseases may spread.
- list three symptoms of gastrointestinal disease caused by bacteria.
- state how food "poisoning" may be prevented in the home.
- explain why asceptic techniques are necessary in a microbiological laboratory.

SEQUENCE: LA-34; ST-34

SUGGESTIONS:

1. Part I of the activity calls for melting agar in test tubes. Students should begin this as soon as possible since it takes some time to melt the agar and the agar must be allowed to cool before being poured.

2. You may wish to conduct a discussion of microbial diseases of the GI tract experienced by members of the class. Most symptoms are due to irritation of the GI lining. Nausea occurs when the stomach lining is irritated. Cramps are due to contractions of muscle cells in the GI wall when the lining is irritated. Fever is a generalized response to infection; muscle aches and dizziness in stomach flu are a generalized response to viruses. Vomiting and diarrhea serve the useful function of quickly eliminating the noxious agent.

3. Students may find a library study of cheese production interesting. A microbiology text or encyclopedia would be helpful in such a project.

4. This might be a good time to invite a medical technologist or pathologist as a guest speaker.

5. In 1900 infections were the number one cause of death in the U.S. Today they are still among the ten leading causes but behind cardiovascular disease, cancer, strokes, and accidents. The decrease in proportions of deaths from infections has resulted from modern methods of prevention of infectious diseases. You may wish to conduct a class discussion of the ways in which infectious diseases are prevented today: control of food and water purity by laws, vaccinations, drugs, hygiene, refrigeration and other preservation techniques.

6. In ST-34, protozoa are referred to as single-celled animals. The students may wonder what distinguishes plants from animals. You may wish to comment on the basic rules of classification at this time.

7. In all three Biomedical courses, we have stressed the difficulties in statistical studies--that they do not constitute proof of a cause and effect relationship. On the other hand, we would not want students to think that statistical studies are not valuable. Section 34-1 described a population study that led to a very important discovery implicating contaminated water as a cause of chlolera. Perhaps this would be an opportunity to point out the importance of statistics in health. You could also mention the population studies on smoking and health problems.

INFORMATION ON LABORATORY ACTIVITY 34:

TEACHING NOTES:

1. One purpose of this activity is to allow students to explore the relation between bacteria and food spoilage. A second is to stress the careful technique needed in handling bacteria, and to introduce students to the concept of sterile technique.

2. Anticipated time: two periods on different days plus a short segment of a third period.

3. To shorten the activity, the preparation of agar plates and the growing of bacteria on them may be eliminated, or done as a teacher demonstration, or done by only a few students.

4. Nonfat milk is best for this activity because fat may confuse the interpretation of the results by forming a separate layer on top of the milk. However, any type of milk will work.

5. Motile bacteria are usually present in food up to three days after incubation is begun. After that, few motile bacteria will be seen. Therefore, the microscopy (Part II) should be done within three days after incubation is begun. After three days, there will still be many bacteria, but they will not be motile.

6. It may be helpful to students if you demonstrate how to pour agar into a sterile Petri dish. It may also help to demonstrate how to handle the test tube caps (Part I) and the transfer of food onto the agar plate (Part II) with a sterile loop.

7. Disposable Petri dishes are already sterile. To eliminate making agar, pre-poured agar plates may be purchased from local medical or scientific supply houses, or a hospital lab might give away their outdated ones. These are still useful for LA-34.

8. If inoculating loops are unavailable, they can be made from paperclips or wire. Unbend the paperclip and twist the end into as small a loop as possible. Make a handle for it by inserting the other end in a cork, or by inserting it in a thick glass tube and melting the end of the tube in a flame. Sterile Q-tips can be used instead of loops if one removes them carefully from the package. They are acceptable even if the package is not labelled "sterile."

9. Part I calls for test tubes of sterile agar. Special plastic or aluminum test tube caps are the usual means to keep dust out. If the caps are

unavailable, substitute caps are easily made by taking a double thickness of aluminum foil and shaping it over the mouth. The cap must extend down about two to three centimeters below the lip, to keep dust out. Be sure the homemade cap can be removed and replaced easily.

10. For incubators, see Teaching Notes, LA-12, Period I, Teaching Note 7.

11. Agar plates may be stacked on one another in the incubator. Plates should be inverted to prevent water of condensation from settling on the agar surface. This would cause colonies to run together. Poured plates should be kept in the refrigerator until they are used in Part II.

12. There are many optional activities relevant to nutrition and microbiology. Here are some possibilities.

a. Transfer some of the bacterial growth from the agar into a drop of water on a slide, and examine microscopically (Part III).

b. Cabbage broth may be made by boiling chopped cabbage for 10 minutes. Since some bacterial spores on the cabbage are not killed by boiling for a short time, the broth will often teem with bacteria after 24 hours of incubation. Other foods or vegetables may be tested too.

Less offensive to some in odor than cabbage broth is homemade sauerkraut. To make sauerkraut, halve and core a cabbage, then shred and put alternate layers of cabbage and salt into a container. (About 3 per cent of the total mass should be salt.) Put a plate on the cabbage and weigh the plate down to squeeze the juice out (a gallon jug of water on the plate is one technique). The juice will contain many bacteria in a few days.

c. Examine microscopically and/or plate on agar, foods made by bacterial action: buttermilk, yoghurt, sauerkraut or pickle juice, kafir, cottage and other cheeses. Foods that are dense, such as buttermilk and cheese, should be suspended in water in order to observe them microscopically.

d. The presence of bacteria on everyday objects may be demonstrated by wiping these objects with a sterile Q-tip and then wiping the Q-tip on an agar plate and incubating the plate. You could have students test their hands, faces, the inside of their mouths, the floor, soil, kitchen utensils, etc.

Agar plates can also be touched or sneezed on, coughed on, etc. Use caution with anything that grows on a nutrient-agar plate--it may be pathogenic. An agar plate may be left uncovered, exposed to the air for an hour or more, then covered and incubated. One can keep plates exposed for different times to determine the likelihood of contamination from the air.

e. Test the effect of germicides on bacterial growth in foods. For germicides, you may use alcohol, tincture of iodine, and 3% hydrogen peroxide.

f. Prepared slides of bacteria may be of interest to your students and can be obtained from educational supply houses.

MATERIALS: (for 15 set-ups)

Part I:

15 test tubes, 16 x 125 mm
15 test tube caps, 18 mm (Carolina Biological Supply Co., #73-1474)
15 test-tube holders
nutrient agar powder, 4.65 g
autoclave
15 Petri dishes, sterile
5 to 10 hot water baths
30 beakers, 50- or 150-ml
5 glass-marking pencils
germicide (such as Lysol)
milk (nonfat preferred)
incubator

Part II:

15 inoculating loops
methylene blue staining solution, 20-ml
30 beakers, 50- or 250-ml
15 glass-marking pencils
pH paper, range 1-6 (or 0-11)
60 microscope slides
60 coverslips
paper tissues
30 droppers (or 1-ml pipets)
30 toothpicks (or pieces of wire)
15 microscopes
germicide
15 gas burners
incubator

Part III:

15 mm rulers

PREPARATION OF REAGENT:

Methylene blue: A large quantity of stock solution was prepared for LA-10, Unit I. See Teaching Notes for that activity for making a stain from the stock.

PREPARATION OF MATERIALS:

The only item to be prepared is tubes of sterile nutrient agar.

Autoclaving is the most time-consuming aspect of the preparation. Some schools have electric pressure cookers for autoclaves, which may take as long as 45 minutes to warm up. It is wise to start the autoclave early, before you begin preparing the items; this will insure that it is warmed up when you are ready to put the items into it.

The materials necessary for making tubes of sterile nutrient agar for 15 set-ups are:

flask, 500-ml
15 test tubes, 16 x 125 mm
15 test tube caps, 18 mm
nutrient agar powder, 4.65 g
hot water bath (or direct heating set-up)
stirring rod
balance
autoclave

1. Calculate how many ml of agar are needed: 10 ml per set-up, more for some of the options discussed in the Teaching Notes.

2. 31 g of powdered nutrient agar make 1,000 ml of agar. Calculate how many grams of powdered agar you need, and weigh out this amount. For 15 set-ups you would need 150 ml of agar and 4.65 g powder.

3. Measure out a volume of tap water equal to the amount of agar needed, put it in a 500-ml flask and then add the measured powder to the water.

4. Dissolve the agar with heat. Use a hot water bath or, to heat it faster, heat the agar directly while stirring. It is important to stir if direct heat is used, otherwise the agar may burn on the bottom. Don't stop stirring until the agar is dissolved, for it may burn. Agar also has a tendency to foam over when it boils.

5. When the agar has completely dissolved, dispense about 10 ml of the agar into each test tube, one test tube per set-up. Suggestion: Note the fluid level of 10 ml of water before pouring the agar.

6. Cap the test tubes. See Teaching Note 9.

7. Autoclave the capped tubes for 20 minutes at pressures of 15 to 20 lb/sq in. Don't depressurize the autoclave too fast afterwards or the tubes will boil over.

8. Allow the tubes to cool, and set them aside for the activity.

ANTICIPATED RESULTS:

Part II

1. The following is based upon observations in our lab. Your results may differ from ours. After 24 hours of incubation, the milk showed the separation

of a white precipitate on the bottom (a curd). This is protein that has been coagulated by acids or enzymes produced by bacteria. A fat layer floated on top of whole milk, and there was none in nonfat milk. A transparent cloudy fluid (whey--pronounced "way") was seen. There were gas bubbles and a strong odor produced by the bacteria. The milk kept at the cooler temperature showed fewer changes at first.

2. The pH of the incubated milk may be the same or slightly lower than that of the other milk sample, due to acid produced by bacteria.

3. Microscopic appearance--there is great variability in the bacterial flora in milk. Our results are given below.

The 24-hour incubated milk contained many motile rod-shaped bacteria visible under high power. Non-motile ones were seen too. In addition, epithelial cells from the lining of the cow's udders were seen. These are large flat polygonal cells. A whole milk sample showed large numbers of spherical fat globules, low-fat milk showed fewer of them, and nonfat had hardly any.

Milk kept at room temperature contained little or no bacteria after 24 hours. After 4 days, there were many non-motile rods present in both the incubated and room-temperature milk, as well as spherical bacteria in chains (Streptococci).

The stain makes bacteria easy to see and stops them from moving. Cabbage (Teaching Note 12B) also contained many motile bacilli after incubation.

Part III

Growth on agar showed individual colonies as well as smears of growth. Each colony grows up from a single bacterium or clump of bacteria that landed on the agar away from other bacteria. A smear indicates many bacteria landed near each other and the resultant colonies overlapped.

There may or may not be an equal number of bacteria on each side of the plate. After 24 to 48 hours, in our samples the growth was predominantly white, though occasional yellow colonies were seen. Luster was dull. Diameter of the colonies varied from .2 mm to 4 mm. The edge of growth was smooth. Height of colonies was ≈ 1 mm, with a convex or flat surface. There was a decaying or sharp odor, but not as strong as the incubated milk's.

The amount of growth depends on the temperature and length of time of incubation.

Molds may also be found on the plate. They may appear black, white, or other colors, and are likely to be filamentous.

ANSWERS TO DISCUSSION QUESTIONS:

1. The sample of milk incubated at a warm temperature.

2. Answers will vary.

3. See Anticipated Result 1.

4. Cottage cheese is made by adding a culture of a certain bacterium to skim milk and allowing it to incubate. The watery liquid that separates from the protein precipitate is removed by draining. Cream and salt are sometimes added by the manufacturers ("creamed cottage cheese") afterwards to alter the flavor.

5. No. The bacteria that gave rise to the colonies were either (1) in the milk when it was bought or (2) got into the milk while it was handled during the activity, such as from the beaker or the air. Which is true is not evident without a carefully-designed experiment.

6. You could incubate milk in the original milk container or plate the milk directly from the container.

7. The milk could have been contaminated from the beaker in which the milk was incubated, or from the air when the beaker was uncovered, or from the droppers or pipets used to transfer the milk to slides.

8. There is likely to be an unequal distribution of growth. This is because it is difficult to spread the milk over the entire plate in a uniform manner.

9. $C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6$ (glucose) + $C_6H_{12}O_6$ (galactose)

10. Agar is a carbohydrate which in aqueous solution solidifies below 40 °C. Agar is obtained from certain seaweeds. Nutrient agar is agar with NaCl, peptones (hydrolyzed proteins) and beef extract added to nourish bacteria.

LESSON 35: (A) PARASITIC DISEASES

(B) OBSERVATION OF LIVE BACTERIA

RATIONALE:

In ST-34 food and waterborne bacterial diseases were considered. ST-35 examines food and waterborne diseases caused not by bacteria but by worms and protozoa. On a worldwide basis, these are among the most common diseases of all. Live bacteria are observed in the laboratory activity, to provide more experience with microbiological techniques.

OBJECTIVES:

The student will:

- define the terms parasite and give three examples of parasitic diseases.
- define cyst and larva, and explain their role during the life cycle of the trichinosis worm.
- describe the life cycle and mode of transmission of at least one animal parasite.
- explain how to prevent infection of at least two animal parasites.

SEQUENCE: LA-34 (cont.); ST-35

SUGGESTIONS:

1. Bacteria are difficult to focus on with the microscope. You may wish to point this out to students and to review this technique before the laboratory activity.

2. Parasites are a common health problem with dogs and other pets. Some students may have had pets with parasites and may be interested in a discussion of this topic. A visit to a veterinarian's clinic might be of interest.

3. ST-35 emphasizes pork as a source of trichinosis. This kind of infection can also result from eating bear meat or (presumably) from cannibalism.

LESSON 36: WATER PURIFICATION

RATIONALE:

Food and water are essential to all life. However, food and water may both carry organisms and/or chemicals that are harmful to the human body. Some of the diseases caused by such organisms were discussed in ST-34 and ST-35. ST-36 is devoted to describing the methods currently used to remove harmful agents, both biological and chemical, from drinking water. In LA-36 the students construct a water-purification column and are given the opportunity to design and carry out a study of water pollution in their community.

OBJECTIVES:

The student will:

- list two bacterial diseases that can be transmitted by contaminated water.
- describe at least one method used by water treatment plants to remove bacteria from drinking water.
- list at least three toxic chemicals that are sometimes found as contaminants of drinking water.
- describe how to construct a water-purification column to remove chemicals from water.

SEQUENCE: ST-36; LA-36

SUGGESTIONS:

1. Some students may be interested in researching the literature suggesting a possible relationship between water pollution and diseases such as cancer, heart disease, chemical poisoning, etc. It might also be interesting for students to research federal or local laws regulating the disposal of chemical wastes by industrial plants. Perhaps the students could locate some information on purification procedures that have been developed for the removal of chemicals from drinking water. This would relate to both ST-36 and LA-36. A three-part report entitled, "Is the Water Safe to Drink?" (Consumer Reports, June, July and August 1974), provides some interesting information on these topics.

2. The possibility of a field trip to a local water treatment or sewage treatment plant is mentioned in the Teaching Notes for LA-36.

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INFORMATION ON LABORATORY ACTIVITY 36:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate a method for removal of chemical pollutants from water and to give the students an opportunity to plan and carry out an investigation of water pollution in their community.

2. Anticipated time: two periods.

3. Parts I and II of this activity should probably be scheduled at least one week before Part III in order to give the students time to plan their projects and collect the samples they will need.

4. Although Parts I and II are designed for teams of two, the students may wish to form larger groups for Part III.

5. The glass wool, activated charcoal and sand are all readily available at most pet stores.

6. A very dilute solution of acetic acid was used in Part II because the small quantity of activated charcoal used in the column is not capable of adsorbing a large number of organic molecules. In fact, the students may find that the column fails to remove all the odor from the 0.01 M acetic acid solution for this reason. The activated charcoal may become saturated before all the acetic acid molecules have been adsorbed.

7. All of the equipment should be washed with an odorless cleanser such as Alconox (Scientific Products #C6300).

8. Note that the acrylic tubing called for in this activity is the same as that used in LA-15 of Unit I.

9. For Part III, you may wish to have the students discuss their plans with you before beginning the investigation and provide a written or oral report when they complete it.

10. An alternative or supplementary activity would be a field trip to the local water treatment or sewage treatment plant.

11. In Unit I, Biomedical Social Science, Lessons 40 to 45, the students conducted surveys on different aspects of their community. If any students happened to study water pollution, they might have something of interest to report to the class at this time. Also they might enjoy an opportunity to extend their survey in this activity.

MATERIALS: (for 15 set-ups)

- 1.08 ml acetic acid (CH_3COOH), glacial
- 15 lengths of acrylic tubing, 22 mm I.D., 30 cm long
- 15 rubber stoppers, one-hole,#4
- 15 lengths of glass tubing, 3/16" x 1/16", 2 to 3" long
- 15 lengths ot latex tubing, 3/16" x 1/16", 2 to 3" long
- 15 pinch clamps
- 15 mortars and pestles
- 15 ring stands with clamps
- 30 beakers, 250-ml
- 30 Erlenmeyer flasks, 125-ml
- 45 beakers, 50-ml
- 15 long glass stirring rods
- 15 scoopulas
- 1 box glass wool (approx. 12 g)
- 1 to 2 boxes activated filter carbon (approx. 1 lb/box)
- 700 ml coarse sand
- odorless cleanser
- distilled water (in squeeze bottles, if available)
- 15 graduated cylinders, 10-ml
- 15 glass-marking pencils
- Parafilm

PREPARATION OF REAGENTS:

0.01 M acetic acid, 1800 ml: 1.08 ± .01 ml glacial acetic acid + sufficient water to give a total of 1800 ml.

ANTICIPATED RESULTS:

In Part II of the activity a significant difference was noted in the odor of tap water before and after it was filtered through the column. No odor could be perceived after filtration. When compared with the "control," a barely perceptible odor could be perceived in the filtered 0.001 M acetic acid solution, but the odor was much less than that of the unfiltered 0.001 M acetic acid solution. Filtering the 0.01 M acetic acid solution produced only a slight reduction in odor.

ANSWERS TO DISCUSSION QUESTIONS:

1. The column was very effective in filtering odorous chemicals out of tap water, fairly effective in filtering the 0.001 M acetic acid and not effective in filtering the 0.01 M acetic acid.

2. The column was ineffective in filtering the 0.01 M acetic acid solution because the quantity of acetic acid molecules exceeded the capacity of the column. That is, all the "active" sites on the charcoal were saturated before the acetic acid molecules had been removed from solution.

3. The effectiveness of the column might be improved by using more charcoal and/or by using smaller particles of charcoal to increase the adsorptive surface area available. Both of these changes would also lengthen the time it takes for a sample to flow through the column, thus increasing the time the sample is in contact with the adsorptive surface of the charcoal.

LESSON 37: (A) FOOD PROCESSING
(B) NITRITES IN FOODS

RATIONALE:

Foods that have been processed in various ways to permit short- to long-term storage make up a large portion of the average person's diet. Processed foods differ from unprocessed foods in at least two ways: nutrients may have been lost or removed during processing and many different types of additives may have been used in the processing. These factors are of importance in evaluating the nutritional quality of a diet. ST-37 provides information on food processing and how it may alter the nutritional content of foods. In LA-37 the students analyze foods to determine the amount of nitrite present as a result of processing.

OBJECTIVES:

The student will:

- list three reasons for food processing
- explain how milling changes the nutritional value of grains.
- define fortification and give at least two examples of foods that have been fortified
- explain how canning, freezing and dehydration prevent the spoilage of foods
- explain how canning, freezing and dehydration alter the nutritional value of food
- determine the concentration of nitrite in some processed foods

SEQUENCE: LA-37; ST-37

SUGGESTIONS:

1. If any of the students have done any home canning they may wish to tell the class about the procedure and the various precautions involved to prevent food poisoning.

2. Field trips to food processing plants are usually interesting. If there are any such facilities in your area you might consider the possibility of such an activity.

3. Food processing is a controversial topic in nutrition, as discussed in the text. Speakers with different viewpoints on the issue of food processing could be invited to contribute to this lesson. The FDA can recommend speakers, as can industrial corporations. Many health food stores can provide the names of proponents of unprocessed, "natural" foods.

INFORMATION ON LABORATORY ACTIVITY 37:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate how a potentially harmful food additive (nitrite) can be analyzed for in foods.

2. Anticipated time: Part I--one period; Part II--one-half to one period.

3. The activity calls for pieces of meat. However, you may also find other listing nitrite as an ingredient, such as canned meat stews. In any case, use a food which has or is likely to have some added nitrite. Suggested foods are those which list nitrites in the ingredients, including hot dogs, bologna, bacon, salami, sliced beef, and canned meats.

4. Once the color indicator is added (Step 6 in Part I, and Step 4 in Part II) the rest of the part must be completed because the color intensity must be read after 15 minutes. If the activity is stopped before either of these two steps and resumed later, the test solutions should be refrigerated overnight.

5. Each set-up requires 5 grams of food in 50 ml of solution. If this is too small an amount to blend, double the quantities for blending purposes and then use only half for analysis.

6. If there is only one blender per class, mortars and pestles may be used as alternates to cut down on waiting time. Grinding with a mortar and pestle should be done for at least two minutes to break up the food. Soft

meats are best because they have little fiber and so are easiest to break up: these include hot dogs, bologna, and liverwurst.

Another option is to blend one food for the entire class and then subdivide it.

7. The ratio of food to sulfanilic acid solution is approximately 1:10 by weight.

8. The nitrite reagent to be prepared is needed only in Part II. The other two reagents are used in both Parts I and II.

9. In Part II, nitrite concentration is expressed in parts per million (ppm). Students may need to have this kind of concentration unit re-explained. In Unit I, LA-39, ppm were used to express nitrogen dioxide gas concentration in air by volume. Here, ppm are used to express nitrite concentration in food by mass.

10. At the time of this writing there is controversy regarding safe levels of nitrite and nitrate in food. The Agriculture Department has proposed reducing the levels of nitrite and nitrate in many foods. These proposals include the eventual total banning of nitrate and nitrite in bacon and all cured meats except canned ones. (An immediate reduction of the nitrite level in bacon from the present level of 200 ppm to 125 ppm has been proposed.) In addition, Department proposals include reducing the nitrite level in sausages, hot dogs, bologna and luncheon meats from the present level of 200 ppm to 100 ppm, and in those cured meats which are canned to 50 ppm. The problem is to reduce the level of nitrite used in processing to a level where nitrosamines are negligible, and at the same time retain enough preservative to prevent botulism.

It should be noted that the present level of 200 ppm would rarely be found in a sample of processed meat. The nitrite concentration decreases significantly over a period of time, since nitrite reacts with oxygen to form nitrate. For example, if nitrite is added to meat prior to packaging until a concentration of 200 ppm is obtained and then the meat is packaged and analyzed a few weeks later, the new nitrite concentration is likely to be as low as 1 to 10 ppm.

MATERIALS: (for 15 set-ups)

- 250 ml conc. HCl
- 15 g sulfanilic acid crystals ($H_2NC_6H_4SO_3H \cdot H_2O$) (Sigma S 4127)
- 0.2 g N-(1-naphthyl)-ethylenediamine dihydrochloride (Sigma N 9125)
- 0.5 g sodium nitrite ($NaNO_2$)
- meat samples
- 1 to 5 blenders (mortars and pestles if only 1 or 2 blenders are available)
- 30 beakers, 150-ml
- 30 beakers, 50-ml
- 15 pipets, 10-ml
- 30 pipets, 1-ml
- 105 cuvets, 16 x 125 mm, Pyrex
- 15 graduated cylinders, 100 ml
- 15 funnels
- 15 stirring rods
- 15 balances
- 10 BIP colorimeters
- 5 to 10 knives (or spatulas)
- filter paper, Whatman #1, 15-cm
- 15 test-tube racks
- 90 corks, #4
- 15 glass-marking pencils
- 15 pieces graph paper

PREPARATION OF REAGENTS:

These reagents were used in Unit I, LA-39. You may still have some of the second reagent below, and it may be reused here. The other two were used up or were unstable.

Sulfanilic acid solution, 1500 ml:

Add 250 ± 1 ml conc. HCl to 1250 ± 10 ml water. Start heating the acid-water solution to 40-45 °C. Add 15 ± 0.1 g of sulfanilic acid crystals. Maintain the temperature at 40-45 °C. The crystals will dissolve with stirring. May be stored at room temperature for a month.

N-(1-naphthyl)-ethylenediamine • 2HCl solution, 200 ml:

Add 0.2 ± .01 g of the powder to 200 ± 2 ml water. To help dissolve it, use a stirring rod to break up the clumps, and stopper and shake. It takes about 5 minutes to dissolve. The solution is stable for several months if kept refrigerated in a stoppered brown bottle.

Sodium nitrite solution, 5 ppm, 400 ml:

Dissolve 0.5 ± .01 g sodium nitrite in a total volume of 250 ± 5 ml water. Dilute 1 ± 0.01 ml of the solution to 400 ± 5 ml. Refrigerate. This solution is stable for only a few days.

ANTICIPATED RESULTS:

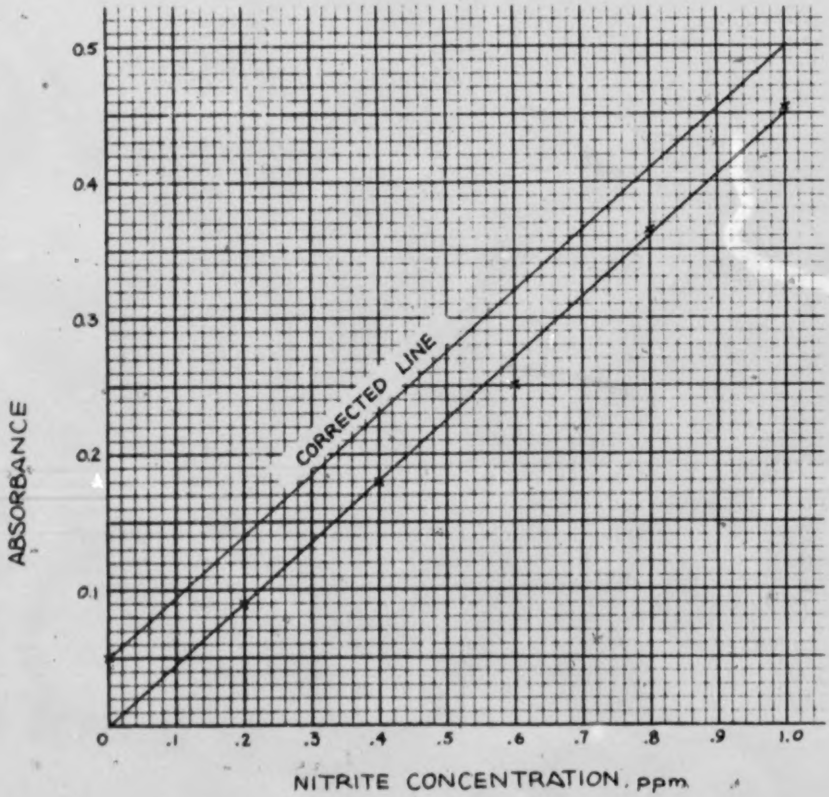
We obtained the following results for the standard tubes.

TUBE	$[NO_2^-]$ in ppm	% T	ABSORBANCE
0	0	100	.000
1	1.0	35	.455
2	.8	43	.365
3	.6	56	.250
4	.4	66	.180
5	.2	81	.090

% T of the "no dye" tube from Part I was 90, corresponding to an absorbance of 0.05.

The graph is shown.

For our hot dogs, bologna, Italian salami and sliced beef, we obtained 1-.5 ppm for the meat solution, which corresponds to 1-5 ppm in the meat. This is reasonable since nitrite is oxidized to nitrate after packaging. See Teaching Note #11.



LESSON 38: FOOD ADDITIVES AND HEALTH

RATIONALE:

A variety of chemicals are added to foods when they are processed, for a number of reasons (preservation, fortification, etc.). Such chemicals are called food additives. Because almost all processed foods contain at least some food additives and because we consume a great many processed foods, it is appropriate to consider the effects these additives may have on our health. ST-37 discusses some of the more common food additives. The controversy surrounding the use of nitrites and nitrates is discussed in some detail to illustrate the growing concern that certain food additives may be detrimental to health.

OBJECTIVES:

The student will:

- list at least four classes of food additives and their uses
- describe the procedure that must be followed before a new food additive is approved for use by the FDA
- state the purpose of adding nitrites and nitrates to foods
- describe the way in which nitrites affect the oxygen-carrying capacity of the blood
- define the term carcinogenic
- discuss the connection between nitrites, nitrosamines and the concern that nitrites in foods may cause cancer in humans.

SEQUENCE: LA-37 (cont.); ST-38

SUGGESTIONS:

Two or more students might organize a debate on the "pros and cons" of food additives for presentation to the class. Reference material on food additives can be obtained from the FDA, the Journal of Nutrition and magazines dealing with "organic" foods. One book which might be helpful is Ruth Winter's, A Consumer's Dictionary of Food Additives, Crown Publishers, N.Y., 1972.

LESSON 39: FOOD LABELS

RATIONALE:

In ST-37 and ST-38 the processing of foods and the use of food additives were considered. ST-39 discusses the importance of food labels as a source of information on nutrients and food additives present in processed foods. In Activity 39 the students use the information contained in food labels to compare different brands of the same food in terms of nutrients, additives and cost.

OBJECTIVES:

The student will:

list the types of information that are required by federal law to appear on the labels of packaged foods

explain how to determine which ingredients listed in food labels are present in the highest percentages.

list at least two types of food that are exempt from the nutrition-labeling laws.

evaluate different brands of the same foods for nutrient value, presence of additives and cost.

SEQUENCE: ST-39; Activity 39

SUGGESTIONS:

1. A good topic for class discussion might be additional types of information that students think should appear on food labels. For example, a number of the flavoring ingredients used in soft drinks are "top secret" and do not appear on labels.

2. Students may be curious to know about the significance of the series of lines and numbers that are often found on packaged food. These lines constitute the Universal Product Code (UPC). The code was designed to be used with a computer, to ring up purchases. This is accomplished by passing a specially designed sensor over the lines. The probe transmits information on identity, brand and size into a computer which totals the costs and produces a printed version of all the information. It also maintains inventory information for the merchant.

3. Students may wish to explore the relation between politics and nutrition. There are, of course, powerful lobbies representing the food industries and consumer groups. Political battles on food additives and food processing are common. Interested students can find much material on this subject in the library and in newspapers. You may wish to discuss this topic with your Social Science colleague.

KEY--REVIEW SET 39:

1. Microbes and chemicals.

2. Production of vitamin K and folic acid.

3. Trichinella worms encysted in contaminated meat. By cooking pork thoroughly.

4. Bacteria, viruses, protozoa, fungi.

5. Water treatment plants generally treat water by sedimentation, filtration and chlorination.

6. Chloroform, benzene, ether and others.

7. By using fresh foods.

8. Sodium nitrate may be converted to nitrites. Nitrites may react with secondary amines inside the stomach to form nitrosamines. Nitrosamines may cause cancer.

9. It provides information on quantities of nutrients, relative cost per unit of nutrient and the identity of additives present.

10. Preservation; elimination of pests; improvement of color, flavor or texture, etc.

11. A food additive is any substance added to a food during processing or preparation. Examples include sodium nitrite, gum arabic, dyes which act as artificial coloring, etc.

INFORMATION ON ACTIVITY 39:

TEACHING NOTES:

1. The purpose of this activity is to reinforce the information on food labels and food additives presented in ST-38 and ST-39. Students will analyze food labels to determine the ingredients and nutritional value of packaged foods. They will also consider the cost of the food in terms of its major nutrients.

2. Anticipated time: two to four periods. Part of one period is needed for organization. (Students will need some time to form groups and select

foods to be studied.) At least one period is needed for analysis of the labels and for calculations. Perhaps another one to two periods are needed if oral reports are to be given.

The activity could be shortened by assigning foods to the class or by the instructor supplying the labels. You could have only one member of each group give a report or make the reports a writing assignment. The activity also provides an opportunity for a library research project.

3. It is recommended that students work in groups, and that each group investigate several brands of one kind of food. The students should select packaged foods for which there are several available brands and which have informative, detailed labels. A few possibilities are given in Step 1 of the Procedure. Besides breads, breakfast cereals and peanut butter varieties, other possibilities are canned or frozen fruits, vegetables and dinners, milk and non-dairy creams and snack foods.

4. If time permits, the activity could include a survey of favorite foods of the students and their families. The label research could center on the most popular foods as determined by the survey. Another alternative would be to determine the most popular menu for a meal such as breakfast and do the label study on the items in the selected menu. The school cafeteria might be able to provide information on their most popular offerings.

5. The activity has implications for your colleagues in Biomedical Mathematics and Social Science. The calculations may employ vector multiplication, a technique stressed in Unit II Mathematics. The Biomedical Social Science instructor may be interested in the comparisons of costs and benefits of raw and processed foods.

6. For the research on additives, try to provide as many reference books as possible or send students to the library. Some potentially useful sources follow.

R. Winter, Consumer's Dictionary of Food Additives. Crown Publishers, New York.

Textbooks on nutrition such as C. H. Robinson, Normal and Therapeutic Nutrition, 14th Edition. Macmillan, New York, 1972.

The Merck Index, Merck and Co, Rahway, New Jersey.

United States Pharmacopeia

National Formulary, American Pharmaceutical Association.

Readers' Guide to Periodical Literature

Consumer Reports articles on processed foods.

G. Borgstrom, Principles of Food Science, Volume 2. Macmillan, New York, 1968.

Specifications for Identity and Purity of Food Additives, Volumes 1 and 2. Columbia University Press, New York, 1963.

T. E. Furia, Handbook of Food Additives. Chemical Rubber Co., Cleveland, 1968.

7. A glossary of common food additives is included below. This could be reproduced for the students.

8. The students may need assistance in finding the cost per unit. You may wish to point out that it is not necessary to find the cost per unit of every nutrient given; calculations for vitamins and minerals should be limited to those that are present in significant quantity.

9. The Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, is a good source of information on labeling. Also, information may be obtained from the U.S. Food and Drug Administration, 5600 Fishers Lane, Rockville, Maryland 20852.

10. The activity could include a visit to a health food store or to a food-processing plant. You might invite a speaker who is a proponent of natural foods. If you do this, it might be good also to obtain a speaker who would argue in favor of food processing and food additives.

11. Students may be curious about the set of black and white "bands" which appear on labels. They are for the computerized check-out of goods by stores and are called the "Universal Products Code." The information coded includes the name of the supplier, the product, and the package size. For example, the cash register may print out "Brand X Grn Peas, 11 oz" in response to the coded lines. This information remains in the computer for inventory purposes.

MATERIALS:

food labels (to be provided by students)
references (see Teaching Note #6)

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ANSWERS TO DISCUSSION QUESTIONS:

1-3. Answers will vary depending on foods studied.

4. "Store brands" are usually less expensive than other brands.

5. Packaged foods may last longer and have an appetizing appearance, odor or taste.

GLOSSARY OF FOOD ADDITIVES

Aluminum calcium silicate: An anti-caking agent used mainly in table salt.

Aluminum potassium sulfate: Adjusts pH of baking powder; also used as a cheese bleach.

Benzoic acid: A preservative.

BHA (Butylated hydroxyanisole): An antioxidant used in many foods.

BHT (Butylated hydroxytoluene): An antioxidant.

Butyric acid: An artificial flavor.

Calcium propionate: A mold retardant used mainly in bread.

Chlorine dioxide: A bread bleach.

Diacetyl: Flavoring agent.

Ethylene gas: Used on fruit to hasten or stimulate ripening, and on nuts to loosen the shells.

Fumaric acid: Used to provide tartness in soft drinks and desserts.

Gum arabic: Used as a thickener and stabilizer in dairy products and other foods.

Magnesium carbonate: Used as an alkalizer in baked goods, some dairy products and canned vegetables.

Maleic hydrazide: Used as a sprout inhibitor on potatoes and other root crops.

Methyl bromide: A fumigant used on a wide range of produce and in some dairy products.

Mineral oil: Used on fruit wrappers and on fruits and vegetables.

Psyllium: Stabilizer used in frozen desserts.

Sodium alginate: Thickener used in desserts and dairy products.

Sodium ascorbate: A chemical used in preserving meat, to help it maintain freshness and color. (Sodium salt of Vitamin C)

Sodium benzoate: A preservative.

Sodium citrate (sodium salt of citric acid): Used as a preservative in a wide range of foods.

Sodium iodoacetate: A chemical used to add taste and increase tenderness in chickens.

Sodium phosphate: Used in cooking ham to allow it to absorb the maximum amount of water.

Stannous chloride: Used as an antioxidant in soft drinks and to preserve the green color of canned asparagus.

Sulfur dioxide: Preservative, used in the preparation of fruit and vegetables.

LESSON 40: (A) THE ROLE OF TEETH IN NUTRITION
(B) THE ANATOMY OF THE TEETH

RATIONALE:

This last sequence of four lessons has been included because of the clear relation between nutrition and dental health. The importance of teeth in nutrition is apparent when one considers the fact that the teeth are responsible for the mechanical breakdown of food, a process that facilitates digestion of food both in the mouth and in the remainder of the digestive tract. In fact, the teeth are so important that numerous dental-health professions have evolved. An additional relationship between nutrition and dental health is that poor nutrition can result in dental problems.

In this first lesson, the anatomy of the teeth and their function in nutrition is considered. In the remaining lessons, the development of the teeth, health problems related to dentition and some of the professions involved with dental health are discussed. LA-40 introduces the students to a basic technique in dentistry, the making of dental charts.

OBJECTIVES:

The student will:

- state the function of the teeth in digestion.
- point out the following structures when given a diagram of the mouth: palate, uvula, incisors, cuspids, bicuspids, molars.
- describe the structures and functions of incisors, cuspids, bicuspids and molars.
- point out at least 5 of the following anatomical parts of the tooth when provided with a diagram: enamel, cementum, dentin, pulp, crown, neck and root.
- prepare a dental chart for a classmate including locations of fillings and missing teeth.
- list at least three professions concerned with dental health.

SEQUENCE: ST-40; LA-40

SUGGESTIONS:

1. There are a number of teaching aids which might prove useful in this dental sequence. Some of these are listed below.

a. charts showing the different parts of a tooth

b. scale models of the mouth showing a full set of teeth

c. models showing different types of malocclusion, cavities, fillings, crowns, etc.

d. X-rays taken in a dental office showing cavities

e. X-rays of young children showing both the deciduous teeth and the permanent teeth sitting "below" them in the jaw.

Your dentist might be willing to lend you some of the above material or bring such items to the school and give a short presentation.

2. It would be helpful for students to have access to a file of information concerning dental professions. Directions for organizing such a file on health professions were given on p. 15 of the Instructor's Manual for Biomedical Social Science, Unit I. The counselor at your school may also have such information.

3. A field trip to a school training dentists or dental technicians and hygienists would be very instructive. This possibility was discussed previously in the Introduction to the Instructor's Manual.

4. The students may be interested in a discussion of the comparative anatomy of teeth in different animals. Such material provides a good example of adaptation. For example, omnivores, carnivores and herbivores eat different types of food; and each of these three classes of animals has a characteristic type of dentition. Carnivores such as wolves tend to have larger canines and pointed incisors and bicuspids. Herbivores such as horses, cows and gorillas have a greater number of molars and may lack canines entirely. Omnivores such as humans tend to have a more uniform mixture of the two types of teeth.

Another interesting example of dentition is shown by rodents. These animals have incisors that continue to grow in length throughout their lives. Rodents continuously wear these front teeth down by using them on hard substances such as nuts, roots, wood, etc.

INFORMATION ON LABORATORY ACTIVITY 40:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to observe the structures of the human mouth and to become acquainted with some of the tools and methods used by dentists and dental assistants, such as use of a dental mirror and filling out a dental chart.

2. Anticipated time: one period.

3. The students should be informed about this activity a day ahead of time so that they can make sure their teeth are clean when they come to class. This should avoid most embarrassment. You may wish to have a few toothbrushes and some toothpaste available for students who forget.

4. If some of the students are reluctant to have someone else examine their mouth, have them perform a self-examination. Hand mirrors should be provided for this prupose.

5. You might tell the students that when they are looking for fillings in their partner's mouth, careful observation will be necessary to distinguish porcelain and quartz fillings. These types of fillings are generally found in teeth toward the front of the mouth.

6. Charts #1 and #2 are attached. Classroom quantities should be reproduced before the activity.

MATERIALS: (for 15 set-ups)

30 copies each of Charts #1 and #2
15 dental mirrors
15 red pencils
several hand mirrors (optional)

ANSWERS TO DISCUSSION QUESTIONS:

1. Answers will vary.

2. If students have fewer than 32 teeth it is probable that their wisdom teeth have not yet erupted. Also, some students may have lost teeth due to decay or accident, or had teeth removed by an orthodontist in an attempt to correct a malocclusion.

3. Fillings tend to be more predominant in the back of the mouth for two reasons: (a) brushing is not as effective in removing food particles, and (b) because the irregular surfaces of the teeth provide ample locations where food can become trapped.

CHART #1, LABORATORY ACTIVITY 40:

(A) STRUCTURE OF THE MOUTH

(B) TYPES OF TEETH

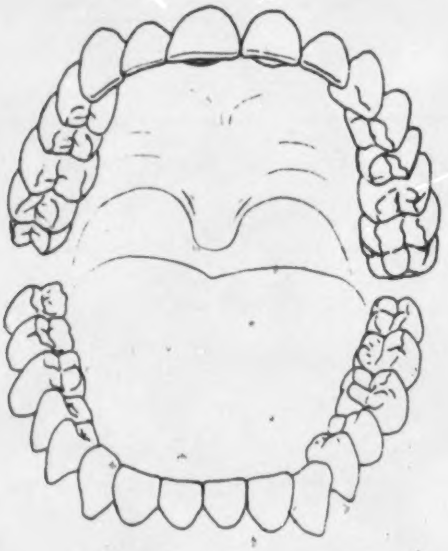


CHART #2, LABORATORY ACTIVITY 40:

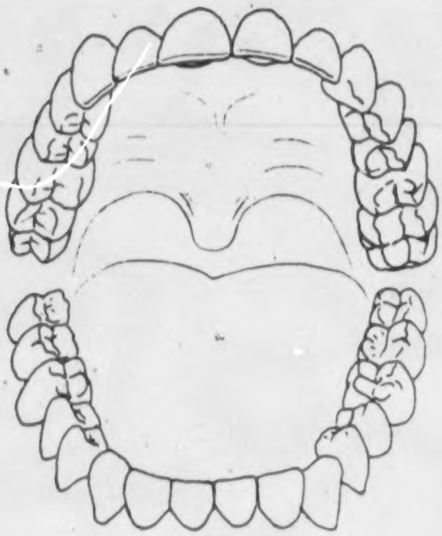
NAME OF PERSON EXAMINED:____________________ SEX:__________

NAME OF EXAMINER:____________________

TOTAL NUMBER OF TEETH:__________

TOTAL NUMBER OF FILLINGS:__________

NUMBER OF TEETH MISSING:__________



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LESSON 41: (A) THE DEVELOPMENT OF THE TEETH AND MALOCCLUSION

(B) DENTAL IMPRESSIONS

RATIONALE:

In ST-41 the development of the deciduous and the permanent teeth is discussed. The importance of proper nutrition for the development of healthy teeth is considered. Malocclusion and the methods used to correct this condition are also covered. LA-41 gives the students the opportunity to make dental impressions of their own teeth.

OBJECTIVES:

The student will:

- explain how poor nutrition may lead to improper dentition.
- define resorption and describe its relationship to the eruption of permanent teeth.
- define occlusion and malocclusion.
- list at least three causes of malocclusion.
- list two methods used to correct malocclusion.
- state the function of dental impressions.
- explain how dental impressions of teeth are made.

SEQUENCE: ST-41; LA-41

SUGGESTIONS:

1. Impacted wisdom teeth are a common health problem. You may wish to provide the students with the following information on this subject.

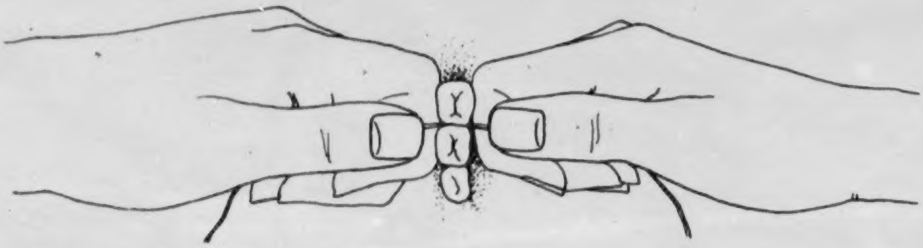
Wisdom teeth are the last teeth to erupt, and often there is not enough room for them in the mouth. If these teeth are unable to erupt we say they are "impacted." Impacted wisdom teeth are frequently the cause of discomfort because they push against other teeth or nerves. When this happens they are usually removed by a dentist. If the extraction is particularly difficult and/or requires the use of general anesthesia, an oral surgeon performs the extraction.

2. This would be a good time to examine dental models showing malocclusion, and some of the methods used to correct it, such as braces, metal bands, etc. Students with braces might be willing to discuss their experiences with orthodontics and allow other students to inspect their braces.

3. One or more students might be interested in researching the relationship between malocclusion, jaw size and human evolution. The incidence of malocclusion in modern man is thought to be high because the size of the jaw has decreased, leaving less room for the teeth. Studies have also been done on the possible relationship between diet, jaw size and malocclusion. A correlation is thought to exist between diets rich in foods that require much chewing (e.g., fibrous foods) and larger jaws. The larger jaw size, in turn, implies less malocclusion.

4. Remind students to bring their toothbrushes for LA-42. It might also be a good idea to have a spool of dental floss on hand to help remove the red stains that will result from chewing disclosing tablets in LA-42. Correct flossing technique could also be demonstrated.

To use dental floss properly, use sufficient length to maintain control (10 to 12 inches) and grasp the floss between the thumbs and index fingers of both hands with about a half-inch of floss stretched between the two hands. Bracing the fingers of one or both hands against teeth, slide the floss at an angle through the contact area, making sure that the floss does not snap against the gums. Manipulate the floss alternately into the gum crevices alongside each tooth, working any debris free of the area. Bring the floss to the contact area again and slide it back through. All material should be removed from the mouth by rinsing.



INFORMATION ON LABORATORY ACTIVITY 41:

TEACHING NOTES:

1. The purpose of this activity is to introduce the students to a technique used in dental offices: the making of dental impressions.

2. Anticipated time: one period.

3. Before the students start the activity, explain that they should not be alarmed when they feel the alginate mixture hardening around their teeth. It is of a rubbery consistency and will not get stuck in their mouths.

4. Students should be cautioned to remove any temporary bridges that they may have in their mouths. Students with braces should not perform this activity.

5. If you wish to have the students make full-mouth impressions, plates for full upper and lower impressions can be obtained from any dental supply house. The alginate and Hydrock may be obtained from the same source.

6. The temperature of the water used to make the alginate mixture is important to ensure proper setting.

7. The scoop used to measure the alginate and Hydrock comes with the alginate mixture.

8. Regular plaster of paris may be substituted for the Hydrock mixture. However, if this is done the consistency of the impressions will not be as good. If you choose to use plaster of paris, consult the package for mixing instructions.

9. We recommend that you perform this particular activity before having the students do it, so that you may be prepared for any questions they may ask. If time allows, you might demonstrate the technique before the students begin.

10. Make sure the beakers are cleaned before the Hydrock hardens. The excess mixture should be placed in a container and thrown out. Pouring it down the sink is not a good idea.

11. The trays that are used to make the impressions are designated "disposable." However, they may be used again if properly cleaned. After the alginate mold has been removed from the plates, the plates should be washed with soap and hot water. They can then be stored and used again the following year.

MATERIALS: (for 30 set-ups)

3 boxes Tra-Ten disposable trays DP bilateral No. 8
3 boxes Tra-Ten disposable trays DP bilateral No. 7
2 lb DP alginate (Type 1) and scoop
10 lb Hydrock Yellow Dental Stone
30 beakers, 150-ml
30 beakers, 250-ml
15 graduated cylinders, 100-ml
15 thermometers
30 spatulas
several hand mirrors (optional)

ANSWER TO DISCUSSION QUESTION:

Answers will vary. Possible causes of malocclusion are discussed in ST-41.

LESSON 42: (A) DENTAL DISEASE

(B) PLAQUE

RATIONALE:

ST-42 discusses the causes, prevention and treatment of some of the most common dental diseases. The relationship between diet and dental disease is also explored. In LA-42 the students examine specimens of plaque microscopically.

OBJECTIVES:

The student will:

- define calculus, caries, periodontal and plaque.
- define periodontitis and gingivitis and state the cause(s) of each.
- describe the relationship between plaque, calculus and dental disease.
- list two ways to reduce dental disease.
- describe the functions of fillings, crowns and bridges.
- discuss the usefulness of mouthwashes.
- describe the relationship between the carbohydrate content of the diet, the texture of food eaten and dental disease.
- describe the microscopic appearance of plaque.
- explain how to evaluate the effectiveness of their toothbrushing technique.

SEQUENCE: ST-42; LA-42

SUGGESTIONS:

1. In ST-42 root canal work on decayed teeth is mentioned but not elaborated on. You may wish to give the students more information on this procedure. The object of root canal work is to remove infected or damaged pulp from the pulp cavity and from the root canals located inside the tooth. The procedure is to remove all the pulp and to sterilize the pulp cavity and root canals. These areas are then filled in with sterile cement and a filling or crown is used to seal off the area and replace the original chewing surface of the tooth. In this way teeth that are badly infected and would have degenerated until their removal would have been necessary, can be saved and rebuilt. The tooth is dead after the procedure, but if properly crowned and properly cleaned at the gumline, it will last as long as a live tooth.

2. It has often been noted that adults show a decrease in the incidence of caries after the age of about 25 years. Perhaps one or more of the students might do some library research on this topic and report to the class.

INFORMATION ON LABORATORY ACTIVITY 42:

TEACHING NOTES:

1. This activity was designed to give the students an opportunity to observe the bacteria that reside in the mouth and to demonstrate the use of disclosing tablets in improving brushing technique. The microscopic examination of plaque should also serve to reinforce some of the techniques introduced in LA-34 on food microbiology.

2. Anticipated time: one period.

3. If the lab period occurs at the beginning of the day the students might be advised not to brush their teeth the morning of the activity. This is to ensure that a sufficient quantity of plaque is present in the mouth.

4. The students may not know how to detect a dirty eyepiece on a microscope or how to clean a dirty lens. An eyepiece can be inspected by looking through it while rotating it. If particles appear to be moving in the field as the eyepiece is turned, then it is dirty. Both eyepiece and objectives should be cleaned only with lens paper. (Tissue paper or paper towels will not only leave lint behind; they may scratch the lens.) When lens paper is used it should be folded to ensure that no oil or sweat from the fingers passes through it to the objective or eyepiece.

5. You may wish to review the concept of Brownian motion, which was initially discussed in LA-34. It is important that the students not mistake a particle being jolted by water molecules for a motile bacterium. One distinction worth making--Brownian motion occurs with both living and non-living particles; motility is a characteristic of life.

6. The students may find it interesting to read about the discovery of bacteria in the mouth. It is described in a letter written by Antony van Leeuwenhoek to the Royal Society of London, dated September 17, 1683. A translation of the letter can be found in C. Dobell's, Antony van Leeuwenhoek and his "Little Animals," Dover Publications, Inc., New York, 1960.

7. Students should be advised to bring their toothbrushes from home. Those who forget might take two disclosing tablets home with them and complete the activity there.

MATERIALS: (for 30 set-ups)

0.8 g sodium chloride (NaCl)
0.1 g crystal violet stain
60 disclosing tablets
toothbrushes
several hand mirrors
30 paper cups
60 toothpicks
15 microscopes
lens paper
30 medicine droppers
60 microscope slides with coverslips

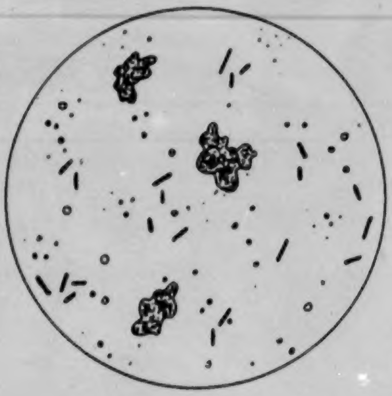
PREPARATION OF REAGENTS:

saline solution, 100 ml: Dissolve 0.8 ± 0.01 g NaCl in 100 ml water.

crystal violet stain, 100 ml: Dissolve 0.1 ± 0.01 g crystal violet stain in 100 ml water.

ANSWERS TO QUESTIONS:

1.

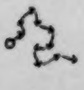


EXAMPLE
(ACTUAL FINDINGS WILL VARY)

2. Yes. (When students focus their microscopes properly, they are almost certain to find bacteria in a scraping.)

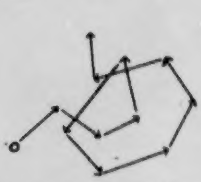
3. Rods and cocci should be present.

4, 5 and 6. Students are likely to see three kinds of movement: Brownian motion, movement of particles on currents that flow across the field and random movement through the field. Schematically these three types of motion might be shown as follows:



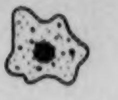
(a) vibration of particle (Brownian motion)

(b) flow across field



(c) random motion

7. Motile bacteria are likely to be present. Their movement follows pattern (c) shown in the answer to Question 6.

8. 

9. 1 to 2 μm

10, 11, and 12. Answers will vary. Plaque is most likely to be found between the teeth.

LESSON 43: (A) VITAMINS AND FLUORIDES IN DENTAL HEALTH
(B) UNIT REVIEW

RATIONALE:

ST-43 completes the discussion of the relation of diet and dental health. The role of vitamins in the development of teeth is considered. In addition, the value of fluoridation of drinking water is discussed. A set of problems based on the entire unit is included for review purposes.

OBJECTIVES:

The student will:

- describe the roles of vitamins A, C and D in the development and maintenance of the teeth.
- explain the difference between the terms "topical" and "systemic."
- compare the effect of topical and systemic administration of fluorides on the incidence of dental caries.
- list the symptoms of too much fluorine in the body.

SEQUENCE: ST-43

SUGGESTIONS:

1. Section 43-2 presents data relating the fluoride content of water and the incidence of dental decay in different communities. The students could use these data to construct a graph for the purposes of estimating the correlation coefficient between fluoride content of water and dental decay. The method for doing this was described in Supplementary Section X of Biomedical Mathematics, Unit II. You may wish to discuss this possibility with your colleague in mathematics.

2. Since fluoridation has long been a controversial issue, you might wish to have people come in to present various sides of the case to the class. Your dentist or a representative of the American Dental Association may be able to suggest the names of persons who would be willing to speak to the class on this topic.

3. Additional information on fluorides can be found in Understanding Dentistry by Lantner and Bender, Beacon Press, Boston, 1969. This book also lists sources from which further information may be obtained. Students interested in learning more about fluoridation of water will have an opportunity to research this topic in Biomedical Social Science, Unit III.

KEY--UNIT REVIEW SET:

1. The study of food composition and how man uses the nutrients for growth and development.

2. a. Level of physical activity, smoking, diet, personality, heredity, sex of individual, obesity.

b. Mostly epidemiological or statistical evidence.

3. a. Food is broken down into simpler molecules that can be absorbed into the body.

b. Carbohydrates, proteins, fats.

4. a. Biological catalysts which speed up chemical reactions.

b. They catalyze the breakdown of food. They catalyze metabolic reactions which transfer energy to ATP.

5. a. In the mouth.

b. In the stomach gastric juice mixes with the food. Some digestion of proteins and carbohydrates occurs here.

6. Excess stomach acid may digest the mucous lining of the stomach or duodenum.

7. a. The liver produces bile, which is stored in the gallbladder. The pancreas secretes pancreatic juice which includes enzymes for hydrolysis of fats, carbohydrates and proteins.

b. In the small intestine.

8. An inflammation of the liver; masses of solid matter formed in the gallbladder; an inflammation of the pancreas.

9. The colon absorbs water, minerals and vitamins from chyme. It also stores and releases feces.

10. Water is the medium in which almost all chemical reactions occur inside our bodies. It is required for regulating body temperature and essential for lubricating the joints.

11. The chemistry of compounds containing carbon; proteins, fats, carbohydrates, vitamins, etc.

12. a. Carbohydrates.

b. Glucose.

13. a. The breaking down of chemicals with the addition of water.

b. The breakdown of proteins, fats and carbohydrates requires hydrolysis.

14. a. Glucose.

b. Excess glucose is converted to fats.

c. Atherosclerosis.

15. a. Sucrose.

b. Vitamins and minerals.

16. a. A fat; an ester of glycerol and fatty acids.

b. Fatty acids and glycerol.

17. a. Saturated fatty acids have no carbon-carbon double bonds; monounsaturated fatty acids have one carbon-carbon double bond; polyunsaturated fatty acids have two or more such double bonds.

b. Saturated fatty acids tend to increase the blood cholesterol level and the risk of atherosclerosis. Polyunsaturated fatty acids have the opposite effect. Monounsaturated fatty acids appear to have no effect on the risk of atherosclerosis.

18. a. Amino acids.

b. Amino (left); carboxyl (right).

c. Proteins.

19. a. Those which cannot be manufactured in sufficient quantity within our bodies.

b. Meat, fish, poultry, eggs and dairy products. These foods are sources of proteins that contain essential amino acids in the ideal proportions.

20. a. Phosphorous, calcium, magnesium, sodium, potassium, iron, zinc.

b. Copper, cobalt, iodine, fluorine, etc.

21. a. Insufficient vitamin B-1 (thiamin).

b. When the nutritious brown hull of rice is removed by food processing, thiamin is removed. If rice is the main source of this vitamin, beriberi may result.

22. a. Fats must be emulsified in order to be digested and absorbed.

b. Bile.

c. No. Hormones are transported to other parts of the body via the bloodstream.

23. a. Kinetic energy is the energy of motion; potential energy is stored energy.

b. Chemical potential energy.

24. a. Energy is neither created nor destroyed when it is changed from one form to another.

b. In all of the processes of cell respiration, energy is transferred or transformed, but there is no change in the amount of energy.

25. Building of large molecules from simpler molecules and conversion of large molecules to simpler molecules with release of energy.

26. Protein, 4 calories; carbohydrate, 4 calories; fat, 9 calories.

27. Glucose is broken down and energy is released for use.

28. ATP is the chemical in which energy generated in cellular respiration is temporarily stored. When energy is required, ATP is broken down into ADP and phosphate, the energy being released for use in biological processes.

29. Products are removed by further metabolism, and the reactions are coupled with ATP hydrolysis thus changing the overall process to an exothermic one.

30. Frequently by lessening the intake of carbohydrates, especially sugar.

31. Expending more calories than are consumed.

32. Use of refrigeration or cooking; processing of foods; use of food additives.

33. a. Pigs.

b. By cooking pork thoroughly.

34. Bacterial, chemical.

35. Iron, niacin, riboflavin, thiamin, pyridoxine, pantothenic acid, vitamin E, phosphorus, magnesium, etc.

36. a. Used to preserve food, to thicken, stabilize, flavor, color, etc.

b. Sodium nitrate and sodium nitrite, used to preserve meat, may be carcinogenic. (Several other answers are possible.)

37. Ingredients, nutrients, additives.

38. Incisors--cut food; cuspids--tear food; bicuspids--cut, tear and grind food; molars--crush and grind food.

39. Malocclusion.

40. Gingivitis is an inflammation of the gums. Periodontitis is an advanced stage of gingivitis characterized by weakening of the gum-tooth relationship.

41. Bacteria multiply in the translucent fluid secreted by the mucous membranes of the mouth. The bacterial waste products mix with the translucent fluid to form plaque. The bacteria in plaque metabolize sugar to acids. The acids are excreted and cause caries.

42. It helps to prevent dental caries, especially in young children.